Read How To Make Atomic Bombs

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CHEMISTRY

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★ A SCIENCE SERVICE PUBLICATION ★

Two Points of View

➤ THE TESTS of the effect of atomic bomb warfare on conditions at sea, which the Joint Army-Navy Task Force plans to conduct this summer, will be interesting to scientists as an opportunity to learn more about the results of this strange, new force. They will scarcely add anything to our fundamental knowledge of atomic science. Because of this there has been some criticism of the amount of money being spent on them.

On the other hand, there has been all too little attention paid to the constructive program for security through international cooperative development, forming the third section of the State Department Report, which is reprinted in this issue of CHEMISTRY. This is a thoroughly adult and realistic appraisal of danger and the way to meet it. It is a far cry from the childish games of hide-and-seek which constitute much of military strategy.

If we are to measure up, in the post-war world, to the position of leadership in world affairs which we claim as due us on account of our technical accomplishment, it is time we applied a little of our vaunted ingenuity to getting along with our neighbors in earnest.

As the nation that invented high-power salesmanship, we ought to be able to find a better approach to the rest of the world than shaking an atomic bomb in its face.

It is now possible for the world to entrust its future to a highly selected group of brilliant scientists. These are men who will act with disinterested wisdom to set our feet on the path to constructive peace. If we miss the chance, because our vision is too short to see the mighty future looming ahead, atomic science in America may descend to the level at which semi-skilled machine operators make weapons for the military, while constructive research takes flight to other countries where it may go forward untrammelled.

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Consulting Editor: PAULINE BEERY MACK (Editor 1927-1944.)

▸ MAP OF *the Marshall Islands, in the Press Club at Kwajalein, where newsmen will watch the location of atomic bomb tests.*

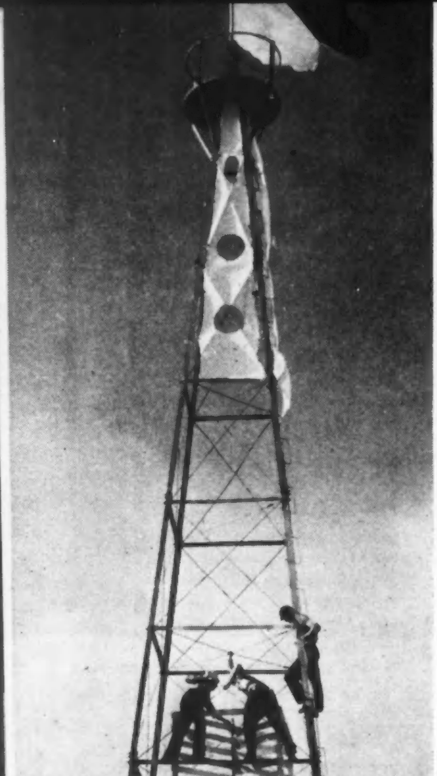
Operation Crossroads

by MARTHA G. MORROW

▸ BIKINI ATOLL, one of the least known island groups in the world until the proposed atomic bomb tests brought it into the limelight, by the end of June will have been as thoroughly scrutinized as any spot on earth. Plants and animals on the island, fish in the lagoon and surrounding ocean, geological formation of the island itself, wind and currents —all are being extensively surveyed prior to the atomic bomb tests to be held during the coming summer.

Until a year or two ago little was known about these palm-covered bits of land in the atoll. The only detailed maps of the region were those captured from the Japanese. Vessels that might have brought back reports on the atoll and surrounding waters were forbidden to go near this or any other atoll of the Jap-mandated Marshalls group.

To biologists these atomic tests, which will drastically reduce all life in the area, offer an ideal man-made



opportunity to study how new life is introduced to a region. After the test biologists will return periodically to explore the possibility of life having survived the explosion and to study new types of life as they appear on the atoll. But first they must know what life exists there today, so the snails, clams, crabs, lizards, lagoon fish, terns and frigate birds are being carefully catalogued.

Not only is Bikini being thoroughly investigated, but neighboring atolls as well. Currents in this region flow in the direction of the Philippine Islands and Asia. Thus Eniwetok atoll, which is down current and might possibly be contaminated by powerful radiations due to the explosion of the atomic bomb, and Rongerik atoll, which is up current and probably won't be contaminated, are both being scrutinized.

The worst that could happen is that every animal on the island will be killed. Then if larvae from neighboring islands could not survive the long trip, life there would fail to return to the island afterwards, unless imported by man. On the other hand, if some animals survive the terrific explosions of these devastating bombs, new species due to the powerful radiations may develop. Certainly if a new type of life is begun, scientists want to be present at its birth.

The soil on Bikini is generally too poor for agriculture. Coconut palms are about the only trees, but there are also some pandanus, breadfruit and papaya. Among food plants, arrow-

➤ Radar reflectors *being installed on a beacon tower at Bikini.*

▸ As COMMANDER *of the Joint Army-Navy Task Force in charge of atomic bomb tests, Vice Admiral W. H. P. Blandy poses in front of the Periodic Table of the elements.*

root is of considerable importance; taro and yams are somewhat less common. A strip of scaevola bushes generally grows as a mangrove thicket along the water's edge. The extent of damage to plant life and how long it takes for the island to regain its vegetation will be determined by precise and long-continued surveys.

When the atomic bomb bursts over Bikini atoll, a lot of fish will undoubtedly be killed. Marine biologists, with the assistance of a corps of expert fishermen, will study the effect of the explosion on fish inshore, in the lagoon and in the open ocean. Reef fish, upon which the natives lived, are expected to suffer, but life in the open ocean probably won't be affected much.

Early objections to the bombing experiments, on the score of possible material harm to commercial fisheries and the whaling industry, have been overcome by the selection of Bikini atoll as the site. The fish here, though abundant enough, are too far from any possible market to be of economic

➤ THE PILOT *in the foreground controls the drone plane overhead. Several planes of this type will collect air samples and make automatic observations during the tests.*

significance, and the little coral island is remote from all known paths of whale migration.

To study where water containing the radiant materials will drift, a contamination survey is being planned. Tests will show the amount of radiation in the water near the atoll and also some distance from it. This will help determine how soon people can safely return to the region. The irradiated particles will also show the path followed by the ocean currents in this region, concerning which little is known at present.

There are over 20 islands in the atoll, of which Bikini is the principal one. This coral ring, 21½ miles long, is about 2100 miles from Honolulu and 2450 from Yokohama. The 167 men, women and children living on the island, of Melanesian and Chammoro, extraction, consented to be moved to a previously uninhabited island 109 miles east, in the Rongerik atoll.

An atoll is formed from a bed of live coral which is thought by some scientists to have been built upward gradually from submerged mountain peaks that at some time in the geological past rose close to the surface

of the sea. Presumably because the coral polyps at the edges of the bed, and particularly to windward, receive more food, they build more rapidly and form an irregularly circular reef of live coral surrounding a shallow lagoon. The maximum depth of the Bikini lagoon is about 200 feet. The bottom is flat and sandy except where cones of live coral rise to or near the surface.

By breaking off fragments of coral and carrying them inward, the waves have created islands here and there around the reef. Elsewhere the reef, typical of atolls, rises only to or near the surface of the sea at high tide, and is broken at one or more places by passages through which the tides flow to and from the lagoon.

Geologists hope to find the depth of the coral layer through the atomic bomb explosion and to determine definitely whether the peak upon which the atoll is built is of volcanic origin. After an explosion has been set off, much can be told concerning the type of material through which the vibrations travel by clocking the time needed for them to be "echoed" back to the surface by the various layers.

Waves near the explosion are expected to be several scores of feet high but the wave height will rapidly decrease much like the height of ripples when a pebble is dropped into a pond. Thus, the waves will probably not break over any of the islands in the atoll even though the highest point on any of these is only about ten feet. "Wave people" are on the scene to measure the height, wavelength, and speed of the waves with instruments, cameras, echo-sounding machines, and television.

➤ SHANGRI-LA, *the Flattop, will carry helicopters for radiological observations after the bomb explosion.*

➤ Crossroads *Instrumentation Unit will wear this shoulder patch.*

Unanswered questions include how such waves would act and how much surrounding islands would interfere with their normal course. All the instruments set up to measure the waves are remote controlled so that the people in charge will be a long, long way off.

A number of institutions are taking part in this scientific survey. They include the U. S. Navy Hydrographic Office, the Woods Hole Oceanographic Institution, U. S. National Museum, the Fish and Wildlife Service of the U. S. Department of the Interior, the U. S. Geological Survey, and the U. S. Coast and Geodetic Survey. The University of California through its College of Engineering and the Scripps Institution of Oceanography, the University of Southern California and the University of Michigan will also be represented. The U. S. Navy Electronics Laboratory at San Diego, the Geotechnical Corporation of Boston, the U. S. Navy Mine Warfare Test Station at Solomon's Island, Maryland, and the Bureau of Ships of the Navy Department will also cooperate in the study.

Two ships belonging to the U. S. Navy's Hydrographic Office are already on the scene. Complete floating laboratories, the USS Sumner and the USS Bowditch, include all the equipment necessary to survey the area, test ocean currents, take the temperature of the water, identify material on the ocean bottom and study weather conditions. Both are stocked with all the apparatus needed to design and print maps on the scene. In addition six smaller ships are being employed.

As this area will probably be the center of scientific investigation for years to come, the results of these surveys will be coordinated and published by the newly-established Division of Oceanography of the Hydrographic Office, so that all known information on this closely-scrutinized geographical guinea pig will be available.

On the Back Cover

➤ Not atomic, *this explosion in Bikini Atoll is of an ordinary bomb. Data from preliminary tests of this kind will be compared with that from the big-time explosions to come later.*

Synthetic Exploding Atoms Now Available for Research

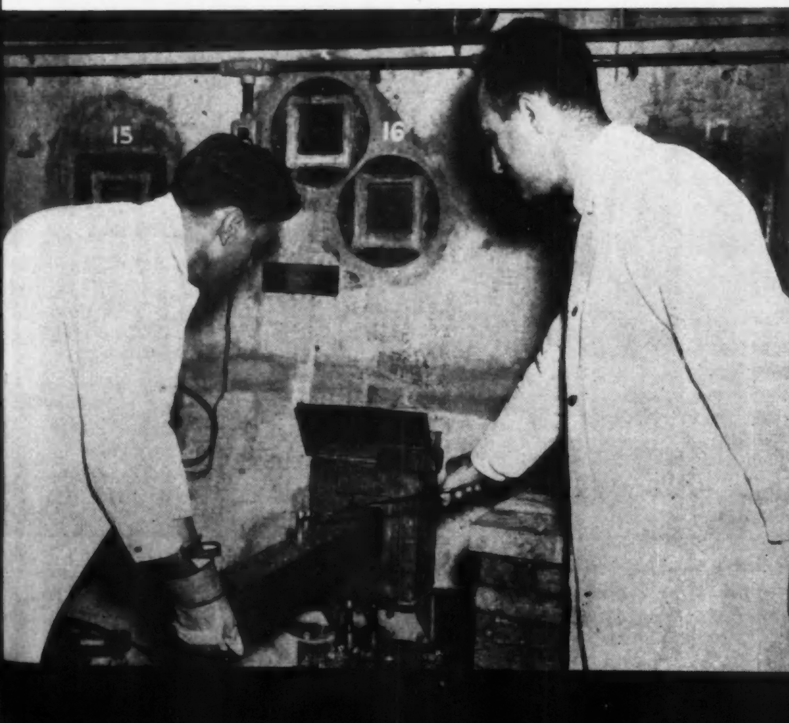
Isotopes To Order

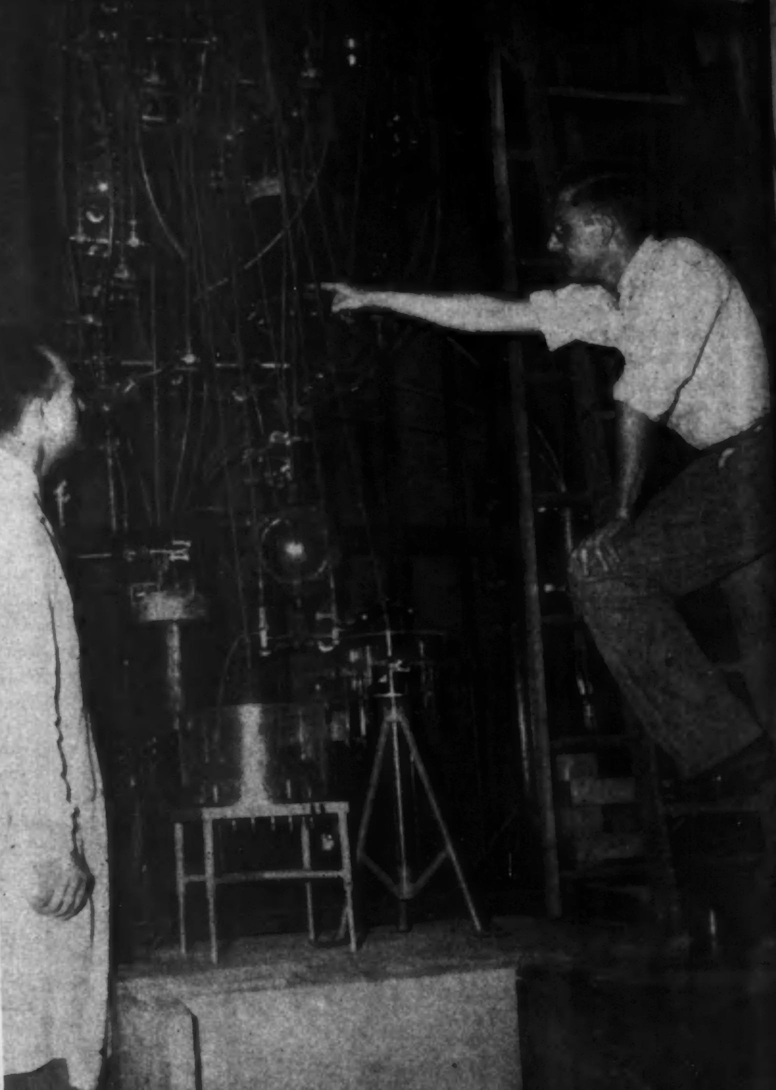
➤ EXPLODING CHEMICAL ELEMENTS, made synthetically in chain-reacting atomic energy piles, which will work for peace instead of war, are the product of a new manufacturing enterprize announced here recently by the War Department's Manhattan Engineer District.

They are what are called the radioisotopes of the common elements. Introduced into familiar substances, these special synthetic kinds of radioactive atoms can be traced through everyday but little understood processes. They can be tracked by means of the rays they give off.

By such "tracer" studies scientists are making headway in understanding how plants build our food out of water, air and sunshine, how com-

➤ THE FAMOUS PILE *where canned uranium slugs perform their chain reactions in a block of graphite. Similar reactions will now make radioisotopes of other elements for use in research. Dr. Cohn loads the container which holds material to be irradiated into the graphite block which will be pushed into the center of the pile.*





➤ CHEMICAL SEPARATIONS *by remote control will be carried out by the apparatus being installed in this shielded panel. Robert Garber shows Dr. Waldo Cohn how it will work.*

▶ LEAD BRICKS *absorb radiations from the material in the beaker, in this semi-hot laboratory. The chemist watches his work in the mirror and handles the apparatus with a relatively short pair of tongs. Equipment of this type is used for radioactive products whose activity has decayed down to a moderate level.*

pounds like the sulfa drugs combat disease, how industrial chemical reactions take place, and how life processes are passed on from generation to generation.

The new manufacturing venture, resulting from atomic bomb research, undertakes to supply to qualified research organizations the radioisotopes which come out of the Oak Ridge chain-reacting piles as fission products of uranium. Many of them were troublesome by-products of the reactions that produced material for the atomic bombs. Now the men who run the piles are looking for the best uses for them.

Since recovery of the minute amounts of many radioactive elements which occur under the conditions which make the bomb elements has not proved practical, experiments have been directed toward the production of the particular isotopes most in demand for research. These are radioactive forms of carbon, sulfur, phosphorus and iodine. All these are furthering new knowledge of life

processes and promise better ways of conquering disease.

Possibilities of isotope production are, however, by no means limited to these elements. Over 400 man-made radioactive isotopes of the 96 elements are known, and the scientists at Oak Ridge are ready to begin negotiations about supplying any of them with a half-life of more than 12 hours.

Under the program announced, approximately 100 radioactive isotopes will be obtainable in varying quantities. Some of the most important of these include carbon 14, sulfur 35, phosphorus 32 and iodine 131. The numbers following the name of the element refer to the mass of the isotope, that is to the total of protons plus neutrons in the nucleus. Ordinarily stable carbon consists of isotopes of mass 12 and 13, sulfur 32, 33 and 34, phosphorus of 31 and iodine of 127.

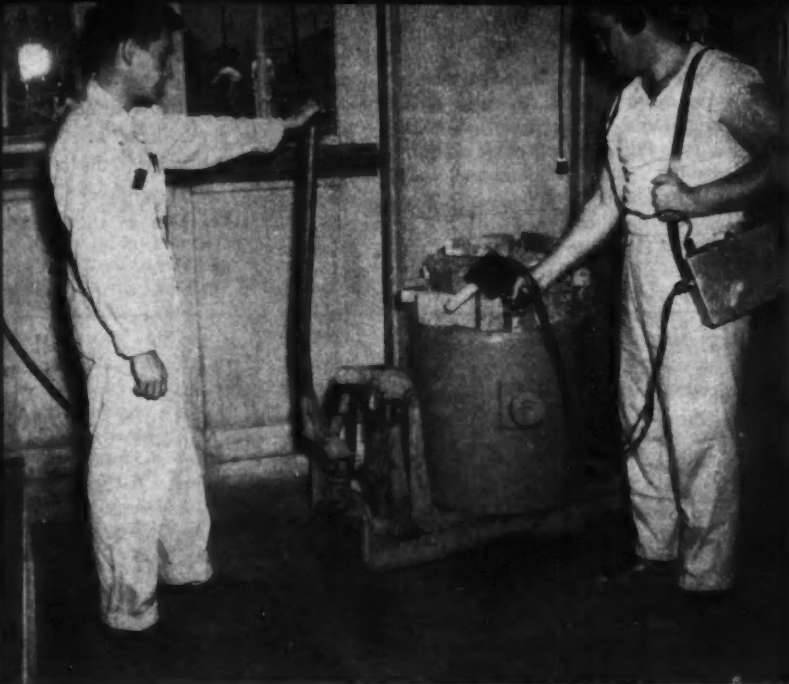
Since carbon is one of the principal elements found in organic material, the isotope carbon 14 is expected to give great impetus to the study of all organic processes including the mechanism and growth of normal and abnormal tissues and all plant and animal functions. In the medical field, at least initially, isotopes will yield their greatest benefits not directly in treatment of disease but as tools for finding the causes of diseases.

Phosphorus, which is important in plant and animal metabolism and human hemotology, is also expected to reveal many biological secrets through experimental use of its isotope—phosphorus 32. At the same time, sulfur 35 may be used in tracing reactions of sulfa drugs. Radioiodine is valuable because of its specific incorporation in thyroxin and thus can be used to study functions of the thyroid gland. These isotopes may also be useful as tracers in industrial chemistry and metallurgy.

The radioactive products have been classified in four groups: In Class A they place those whose long half-life permits stock-piling. These the laboratory will have usually on hand. Isotopes whose radioactivity decays more rapidly, so that they can be made but not stock-piled, are listed in Class B. These can be made to order. Isotopes in Class C are seldom on hand, and produced on an experimental basis only. Those marked Class D can be made, but with difficulty.

Many months of coordinated effort among atomic scientists at various Manhattan Project facilities preceded the release of the radioisotopes for experimental work. Most of the radioisotopes will be prepared at the Clinton laboratories at Oak Ridge operated for the Army by the Monsanto Chemical Company, but the bombardment facilities of the Hanford Engineer Works at Pasco, Wash., now operated by du Pont, to be taken over by General Electric Company about Sept. 1, will also be used. Research will be conducted by the Argonne National Laboratory, which is University of Chicago, operated for the Army, and also at the University of California and Iowa State College.

The isotope distribution will be supervised by an advisory committee nominated by the National Academy of Sciences, with Dr. Lee A. Du Bridge, new president of the California Institute of Technology now at



➤ FROM PILE *to hot laboratory the dangerously radioactive materials are carried in these containers whose walls are so thick that they are nearly all lead. Radiation leaks are being hunted with a probe counter, in this picture, before the load is hauled away.*

the University of Rochester, as chairman. Dr. K. T. Bainbridge of Harvard is sub-chairman of allocation, while all requests for application of radioisotopes for human medical problems will flow through the hands of Dr. Andrew Dowdy of the University of Rochester.

The Manhattan District's isotopes branch is headed by Dr. Paul C. Aebersold, with Dr. W. E. Cohn as chief of the radioisotope development section and Dr. J. R. Coe director of the chemistry division.

Several methods are available for making radioactive isotopes. The cyclotron, original apparatus for atom-smashing, and its younger sister, the betatron, are versatile in the variety of radioisotopes they can turn out, because they can utilize different atom-bombing projectiles at different energies. The chain-reacting pile works by slow neutron bombardment, and can produce isotopes by only two processes, fission and gamma ray radiation, but the yields of elements so produced are enormously greater.

The method of producing any isotope must vary with the quantity wanted and the uses to which it is to be put. For some purposes a minute quantity is sufficient. Some uses would require a high degree of purity, while for others admixture with other isotopes of the same element or with considerable quantities of different elements might not be considered undesirable. In general, the Manhattan Engineer District expects the cost of their isotopes to be cheaper if the users will take them as they come from the pile.

"Tell her there'll be a slight delay in her prescription!"

Problems Simple in Theory But Staggering in Complexity

How To Make Atomic Bombs

When atomic bombs were dropped on Hiroshima and Nagasaki last August, CHEMISTRY *brought its readers, in its September issue, extracts from the report issued by the War Department under the title "A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government 1940-1945," written by Dr. Henry D. Smyth of Princeton University. These extracts dealt chiefly with the new principles of physics and chemistry discovered during the atomic power researches and brought to fruition in the atomic bomb. In October and November,* CHEMISTRY *reprinted from the Smyth Report extracts dealing with the chemistry of the new element, plutonium. Now the Navy's tests of atomic bombs at sea, known to the armed services as "Operation Crossroads," again bring into focus the technical principles of the atom bomb. From that final authority, the Smyth Report,* CHEMISTRY *reprints verbatim the War Department's authorized description of the problems met in the construction of the bomb.*

➤ BY DEFINITION, an explosion is a sudden and violent release (in a small region) of a large amount of energy. To produce an efficient explosion in an atomic bomb, the parts of the bomb must not become appreciably separated before a substantial fraction of the available nuclear energy has been released. (For expansion leads to increased escape of neutrons from the system and thus to premature termination of the chain reaction.) Stated differently, the efficiency of the atomic bomb will depend on the ratio of (a) the speed with which neutrons generated by the first fissions get into other nuclei and produce further fission, and (b) the speed with which the bomb flies apart. Using known principles of energy generation, temperature and pressure rise, and expansion of solids and vapors, it was possible to estimate the order of magnitude of the time interval between the beginning and end of the nuclear chain reaction. *Almost all the technical difficulties of the project come from the extraordinary brevity of this time interval.*

In earlier chapters we stated that no self-sustaining chain reaction could be produced in a block of pure uranium metal, no matter how large, because of parasitic capture of the neutrons by U-238. This conclusion has been borne out by various theoretical calculations and also by direct experiment. For purposes of producing a non-explosive pile, the trick of using a lattice and a moderator suffices—by reducing parasitic capture sufficiently. For purposes of producing an explosive unit, however, it turns out that this process is unsatisfactory on two counts. First, the thermal neutrons take so long (so many micro-seconds)

to act that only a feeble explosion would result. Second, a pile is ordinarily far too big to be transported. It is therefore necessary to cut down parasitic capture by removing the greater part of the U-238—or to use plutonium.

Naturally, these general principles —and others—had been well established before the Los Alamos project was set up.

Critical Size

The calculation of the critical size of a chain-reacting unit is a problem that has already been discussed in connection with piles. Although the calculation is simpler for a homogeneous metal unit than for a lattice, inaccuracies remained in the course of the early work, both because of lack of accurate knowledge of constants and because of mathematical difficulties. For example, the scattering, fission, and absorption cross sections of the nuclei involved all vary with neutron velocity. The details of such variation were not known experimentally and were difficult to take into account in making calculations. By the spring of 1943 several estimates of critical size had been made using various methods of calculation and using the best available nuclear constants, but the limits of error remained large.

The Reflector or Tamper

In a uranium-graphite chain-reacting pile the critical size may be considerably reduced by surrounding the pile with a layer of graphite, since such an envelope "reflects" many neutrons back into the pile. A similar envelope can be used to reduce the critical size of the bomb, but here the envelope has an additional role: its very inertia delays the expansion of the reacting material. For this reason such an envelope is often called a tamper. Use of a tamper clearly makes for a longer lasting, more energetic, and more efficient explosion. The most effective tamper is the one having the highest density; high tensile strength turns out to be unimportant. It is a fortunate coincidence that materials of high density are also excellent as reflectors of neutrons.

Efficiency

As has already been remarked, the bomb tends to fly to bits as the reaction proceeds and this tends to stop the reaction. To calculate how much the bomb has to expand before the reaction stops is relatively simple. The calculation of how long this expansion takes and how far the reaction goes in that time is much more difficult.

While the effect of a tamper is to increase the efficiency both by reflecting neutrons and by delaying the expansion of the bomb, the effect on the efficiency is not as great as on the critical mass. The reason for this is that the process of reflection is relatively time-consuming and may not occur extensively before the chain reaction is terminated.

Detonation and Assembly

It is impossible to prevent a chain reaction from occurring when the size exceeds the critical size. For there are always enough neutrons (from cosmic rays, from spontaneous fission reactions, or from alpha-particle-induced reactions in impurities) to initiate the chain. Thus until detonation is desired, the bomb must consist of a number of separate pieces each one

of which is below the critical size (either by reason of small size or unfavorable shape). To produce detonation, the parts of the bomb must be brought together rapidly. In the course of this assembly process the chain reaction is likely to start—because of the presence of stray neutrons—*before* the bomb has reached its most compact (most reactive) form. Thereupon the explosion tends to prevent the bomb from reaching that most compact form. Thus it may turn out that the explosion is so inefficient as to be relatively useless. The problem, therefore, is two-fold: (1) to reduce the time of assembly to a minimum; and (2) to reduce the number of stray (pre-detonation) neutrons to a minimum.

Some consideration was given to the danger of producing a "dud" or a detonation so inefficient that even the bomb itself would not be completely destroyed. This would, of course, be an undesirable outcome since it would present the enemy with a supply of highly valuable material.

Effectiveness

It was pointed out that the amount of energy released was not the sole criterion of the value of a bomb. There was no assurance that one uranium bomb releasing energy equal to the energy released by 20,000 tons of TNT would be as effective in producing military destruction as, say, 10,000 two-ton bombs. In fact, there were good reasons to believe that the destructive effect per calorie released decreases as the total amount of energy released increases. On the other hand, in atomic bombs the total amount of energy released per kilogram of fissionable material (i.e., the efficiency of energy release) *increases* with the size of the bomb. Thus the optimum size of the atomic bomb was not easily determined. A tactical aspect that complicates the matter further is the advantage of simultaneous destruction of a large area of enemy territory. In a complete appraisal of the effectiveness of an atomic bomb, attention must also be given to effects on morale.

Method of Assembly

Since estimates had been made of the speed that would bring together subcritical masses of U-235 rapidly enough to avoid predetonation, a good deal of thought had been given to practical methods of doing this. The obvious method of very rapidly assembling an atomic bomb was to shoot one part as a projectile in a gun against a second part as a target. The projectile mass, projectile speed, and gun caliber required were not far from the range of standard ordnance practice, but novel problems were introduced by the importance of achieving sudden and perfect contact between projectile and target, by the use of tampers, and by the requirement of portability. None of these technical problems had been studied to any appreciable extent prior to the establishment of the Los Alamos laboratory.

It had also been realized that schemes probably might be devised whereby neutron absorbers could be incorporated in the bomb in such a way that they would be rendered less effective by the initial stages of the chain reactions. Thus the tendency for the bomb to detonate premature-

ly and inefficiently would be minimized. Such devices for increasing the efficiency of the bomb are called autocatalytic.

Summary of Knowledge

In April 1943 the available information of interest in connection with the design of atomic bombs was preliminary and inaccurate. Further and extensive theoretical work on critical size, efficiency, effect of tamper, method of detonation, and effectiveness was urgently needed. Measurements of the nuclear constants of U-235, plutonium, and tamper material had to be extended and improved. In the cases of U-235 and plutonium, tentative measurements had to be made using only minute quantities until larger quantities became available.

Besides these problems in theoretical and experimental physics, there was a host of chemical, metallurgical, and technical problems that had hardly been touched. Examples were the purification and fabrication of U-235 and plutonium, and the fabrication of the tamper. Finally, there were problems of instantaneous assembly of the bomb that were staggering in their complexity . . .

Theoretical Physics Division

There were two considerations that gave unusual importance to the work of the theoretical physics division under H. Bethe. The first of these was the necessity for effecting simultaneous development of everything from the fundamental materials to the method of putting them to use—all despite the virtual unavailability of the principal materials (U-235 and plutonium) and the complete novelty of the processes. The second consideration was the impossibility of producing (as for experimental purposes) a "small-scale" atomic explosion by making use of only a small amount of fissionable material. (No explosion occurs at all unless the mass of the fissionable material exceeds the critical mass.) Thus it was necessary to proceed from data obtained in experiments on infinitesimal quantities of materials and to combine it with the available theories as accurately as possible in order to make estimates as to what would happen in the bomb. Only in this way was it possible to make sensible plans for the other parts of the project, and to make decisions on design and construction without waiting for elaborate experiments on large quantities of material. To take a few examples, theoretical work was required in making rough determinations of the dimensions of the gun, in guiding the metallurgists in the choice of tamper materials, and in determining the influence of the purity of the fissionable material on the efficiency of the bomb.

The determination of the critical size of the bomb was one of the main problems of the theoretical physics division. In the course of time, several improvements were made in the theoretical approach whereby it was possible to take account of practically all the complex phenomena involved. It was at first considered that the diffusion of neutrons was similar to the diffusion of heat, but this naive analogy had to be forsaken. In the early theoretical work the assumptions were made that the neutrons all

had the same velocity and all were scattered isotropically. A method was thus developed which permitted calculation of the critical size for various shapes of the fissionable material provided that the mean free path of the neutrons was the same in the tamper material as in the fissionable material. This method was later improved first by taking account of the angular dependence of the scattering and secondly by allowing for difference in mean free path in core and tamper materials. Still later, means were found of taking into account the effects of the distribution in velocity of the neutrons, the variations of cross sections with velocity, and inelastic scattering in the core and tamper materials. Thus it became possible to compute critical sizes assuming almost any kind of tamper material.

The rate at which the neutron density decreases in bomb models which are smaller than the critical size can be calculated, and all the variables mentioned above can be taken into account. The rate of approach to the critical condition as the projectile part of the bomb moves toward the target part of the bomb has been studied by theoretical methods. Furthermore, the best distribution of fissionable material in projectile and target was determined by theoretical studies.

Techniques were developed for dealing with set-ups in which the number of neutrons is so small that a careful statistical analysis must be made of the effects of the neutrons. The most important problem in this connection was the determination of the probability that, when a bomb is larger than critical size, a stray neutron will start a continuing chain reaction. A related problem was the determination of the magnitude of the fluctuations in neutron density in a bomb whose size is close to the critical size. By the summer of 1945 many such calculations had been checked by experiments.

A great deal of theoretical work was done on the equation of state of matter at the high temperatures and pressures to be expected in the exploding atomic bombs. The expansion of the various constituent parts of the bomb during and after the moment of chain reaction has been calculated. The effects of radiation have been investigated in considerable detail.

Having calculated the energy that is released in the explosion of an atomic bomb, one naturally wants to estimate the military damage that will be produced. This involves analysis of the shock waves in air and in earth, the determination of the effectiveness of a detonation beneath the surface of the ocean, etc.

In addition to all the work mentioned above, a considerable amount of work was done in evaluating preliminary experiments. Thus an analysis was made of the back-scattering of neutrons by the various tamper materials proposed. An analysis was also made of the results of experiments on the multiplication of neutrons in subcritical amounts of fissionable material.

Experimental Nuclear Physics Division

The experiments performed by the Experimental Nuclear Physics group at Los Alamos were of two kinds: "differential" experiments as for de-

termining the cross section for fission of a specific isotope by neutrons of a specific velocity, and "integral" experiments as for determining the average scattering of fission neutrons from an actual tamper.

Many nuclear constants had already been determined at the University of Chicago Metallurgical Laboratory and elsewhere, but a number of important constants were still undetermined—especially those involving high neutron velocities. Some of the outstanding questions were the following:

1. What are the fission cross sections of U-234, U-235, U-238, Pu-239, etc.? How do they vary with neutron velocity?

2. What are the elastic scattering cross sections for the same nuclei (also for nuclei of tamper materials)? How do they vary with neutron velocity?

3. What are the inelastic cross sections for the nuclei referred to above?

4. What are the absorption cross sections for processes other than fission?

5. How many neutrons are emitted per fission in the case of each of the nuclei referred to above?

6. What is the full explanation of the fact that the number of neutrons emitted per fission is not a whole number?

7. What is the initial energy of the neutrons produced by fission?

8. Does the number or energy of such neutrons vary with the speed of the incident neutrons?

9. Are fission neutrons emitted immediately?

10. What is the probability of spontaneous fission of the various fissionable nuclei?

In addition to attempting to find the answers to these questions the Los Alamos Experimental Nuclear Physics Division investigated many problems of great scientific interest which were expected to play a role in their final device. Whether or not this turned out to be the case, the store of knowledge thus accumulated by the Division forms an integral and invaluable part of all thinking on nuclear problems.

Experimental Methods

The earlier chapters contain little or no discussion of experimental techniques except those for the observing of fast (charged) particles. To obtain answers to the ten questions posed above, we should like to be able to:

(1) determine the number of neutrons of any given energy;
(2) produce neutrons of any desired energy;
(3) determine the angles of deflection of scattered neutrons;
(4) determine the number of fissions occurring;
(5) detect other consequences of neutron absorption, e.g., artificial radioactivity.

We shall indicate briefly how such observations are made.

Detection of Neutrons

There are three ways in which neutrons can be detected: by the ionization produced by light atomic nuclei driven forward at high speeds by elastic collisions with neutrons, by the radioactive disintegration of unstable nuclei formed by the absorption of

neutrons, and by fission resulting from neutron absorption. All three processes lead to the production of ions and the resulting ionization may be detected using electroscopes, ionization chambers, Geiger-Müller counters, Wilson cloud chambers, tracks in photographic emulsion, etc.

While the mere detection of neutrons is not difficult, the measurement of the neutron velocities is decidedly more so. The Wilson cloud chamber method and the photographic emulsion method give the most direct results but are tedious to apply. More often various combinations of selective absorbers are used. Thus, for example, if a foil known to absorb neutrons of only one particular range of energies is inserted in the path of the neutrons and is then removed, its degree of radioactivity is presumably proportional to the number of neutrons in the particular energy range concerned. Another scheme is to study the induced radioactivity known to be produced only by neutrons whose energy lies above a certain threshold energy.

One elegant scheme for studying the effects of neutrons of a single, arbitrarily-selected velocity is the "time of flight" method. In this method a neutron source is modulated, i.e., the source is made to emit neutrons in short "bursts" or "pulses." (In each pulse there are a great many neutrons—of a very wide range of velocities.) The target material and the detector are situated a considerable distance from the source (several feet or yards from it). The detector is "modulated" also, and with the same periodicity. The timing or phasing is made such that the detector is responsive only for a short interval beginning a certain time after the pulse of neutrons leaves the source. Thus any effects recorded by the detector (e.g., fissions in a layer of uranium deposited on an inner surface of an ionization chamber) are the result only of neutrons that arrive just at the moment of responsivity and therefore have travelled from the source in a certain time interval. In other words, the measured effects are due only to the neutrons having the appropriate velocity.

Production of Neutrons

All neutrons are produced as the result of nuclear reactions, and their initial speed depends on the energy balance of the particular reaction. If the reaction is endothermic, that is, if the total mass of the resultant particles is greater than that of the initial particles, the reaction does not occur unless the bombarding particle has more than the "threshold" kinetic energy. At higher bombarding energies the kinetic energy of the resulting particles, specifically of the neutrons, goes up with the increase of kinetic energy of the bombarding particle above the threshold value. Thus the $Li^7(p,n)Be^7$ reaction absorbs 1.6 Mev energy since the product particles are heavier than the initial particles. Any further energy of the incident protons goes into kinetic energy of the products so that the maximum speed of the neutrons produced goes up with the speed of the incident protons. However, to get neutrons of a narrow range of speed, a thin target must be used, the neutrons must all come off at the same angle, and the

protons must all strike the target with the same speed.

Although the same energy and momentum conservation laws apply to exothermic nuclear reactions, the energy release is usually large compared to the kinetic energy of the bombarding particles and therefore essentially determines the neutron speed. Often there are several ranges of speed from the same reaction. There are some reactions that produce very high energy neutrons (nearly 15 Mev).

Since there is a limited number of nuclear reactions usable for neutron sources, there are only certain ranges of neutron speeds that can be produced originally. There is no difficulty about slowing down neutrons, but it is impossible to slow them down uniformly, that is, without spreading out the velocity distribution. The most effective slowing-down scheme is the use of a moderator, as in the graphite pile; in fact, the pile itself is an excellent source of thermal (i.e., very low speed) or nearly thermal neutrons.

Angles of Deflection

The difficulties in measuring the angles of deflection of neutrons are largely of intensity and interpretation. The number of neutrons scattered in a particular direction may be relatively small, and the "scattered" neutrons nearly always include many strays not coming from the intended target.

Number of Fissions

The determination of the number of fissions which are produced by neutrons or occur spontaneously is relatively simple. Ionization chambers, counter tubes, and many other types of detectors can be used.

Capture of Neutrons

Often it is desirable to find in detail what has happened to neutrons that are absorbed but have not produced fission, e.g., resonance or "radiative" capture of neutrons by U-238 to form U-239 which leads to the production of plutonium. Such studies usually involve a combination of microchemical separations and radioactivity analyses.

Nuclear Constants

By the time that the Los Alamos laboratory had been established, a large amount of work had been done on the effects of slow neutrons on the materials then available. For example, the thermal-neutron fission cross section of natural uranium had been evaluated, and similarly for the separated isotopes of uranium and for plutonium. Some data on high-speed-neutron fission cross sections had been published, and additional information was available in project laboratories. To extend and improve such data, Los Alamos perfected the use of the Van de Graaff generator for the $Li^7(p,n)Be^7$ reaction, so as to produce neutrons of any desired energy lying in the range from 3000 electron volts to two million electron volts. Success was also achieved in modulating the cyclotron beam and developing the neutron time-of-flight method to produce (when desired) effects of many speed intervals at once. Special methods were devised for filling in the gaps in neutron energy range. Particularly important was the refinement of measurement made possible as greater quantities of U-235, U-238 and plutonium began to be received. On the whole, the values of cross

section for fission as a function of neutron energy from practically zero electron volts to three million electron volts is now fairly well known for these materials.

Some Integral Experiments

Two "integral experiments" (experiments on assembled or integrated systems comprising fissionable material, reflector, and perhaps moderator also) may be described. In the first of these integral experiments a chain-reacting system was constructed which included a relatively large amount of U-235 in liquid solution. It was designed to operate at a very low power level, and it had no cooling system. Its purpose was to provide verification of the effects predicted for reacting systems containing enriched U-235. The results were very nearly as expected.

The second integral experiment was carried out on a pile containing a mixture of uranium and a hydrogenous moderator. In this first form, the pile was thus a slow-neutron chain-reacting pile. The pile was then rebuilt using less hydrogen. In this version of the pile, fast-neutron fission became important. The pile was rebuilt several more times, less hydrogen being used each time. By such a series of reconstructions, the reaction character was successively altered, so that thermal neutron fission became less and less important while fast neutron fission became more and more important—approaching the conditions to be found in the bomb.

Results of Nuclear Physics

The nuclear constants of U-235, U-238, and plutonium have been measured with a reasonable degree of accuracy over the range of neutron energies from thermal to three million electron volts. In other words, questions, 1, 2, 3, 4, and 5 of the ten questions posed at the beginning of this section have been answered. The fission spectrum (question 7) for U-235 and Pu-239 is reasonably well known. Spontaneous fission (question 10) has been studied for several types of nuclei. Preliminary results on questions 6, 8, and 9, involving details of the fission process, have been obtained.

Chemistry and Metallurgy

The Chemistry and Metallurgy Division of the Los Alamos Laboratory was under the joint direction of J. W. Kennedy and C. S. Smith. It was responsible for final purification of the enriched fissionable materials, for fabrication of the bomb core, tamper, etc., and for various other matters. In all this division's work on enriched fissionable materials especial care had to be taken not to lose any appreciable amounts of the materials (which are worth much more than gold). Thus the procedures already well-established at Chicago and elsewhere for purifying and fabricating natural uranium were often *not* satisfactory for handling highly-enriched samples of U-235.

Ordnance, Explosives, and Bomb Physics Divisions

The above account of the work of the Theoretical Physics, Experimental Nuclear Physics, and Chemistry and Metallurgy Divisions is somewhat incomplete because important aspects of this work cannot be discussed for reasons of security. For the same reasons none of the work of the Ordnance, Explosives, and Bomb Physics Divisions can be discussed at all.

How To See the Invisible
And Count the Immeasurable

The Instruments of Atomic Physics

Special techniques are required for work with the particles studied in atomic research. The following extract, which is Appendix I. of the Smyth Report on Atomic Energy for Military Purposes, brings together in handy form for reference the methods by which alpha particles, beta particles, positrons, gamma rays, neutrons and their effects can be measured and counted.

Scintillations

➤ THE CLOSEST approach that can be made to "seeing" an atom is to see the bright flash of light that an alpha particle or high-speed proton makes when it strikes a fluorescent screen. All that is required is a piece of glass covered with zinc sulphide, a low-power microscope, a dark room, a well-rested eye, and of course a source of alpha particles. Most of Rutherford's famous experiments involved "counting" scintillations but the method is tedious and, as far as the author knows, has been entirely superseded by electrical methods.

The Process of Ionization

When a high-speed charged particle like an alpha particle or a high-speed electron passes through matter, it disrupts the molecules that it strikes by reason of the electrical forces between the charged particle and the electrons in the molecule. If the material is gaseous, the resultant fragments or ions may move apart and, if there is an electric field present, the electrons knocked out of the molecules move in one direction and the residual positive ions in another direction. An initial beta particle with a million electron volts energy will produce some 18,000 ionized atoms before it is stopped completely since on the average it uses up about 60 volts energy in each ionizing collision. Since each ionization process gives both a positive and a negative ion, there is a total of 36-000 charges set free by one high-speed electron, but since each charge is only 1.6×10^{-19} coulomb, the total is only about 6×10^{-15} coulomb and is still very minute. The best galvanometer can be made to measure a charge of about 10^{-10} coulomb. It is possible to push the sensitivity of an electrometer to about 10^{-16} coulomb, but the electrometer is a very inconvenient instrument to use.

An alpha particle produces amounts of ionization comparable with the beta particle. It is stopped more rapidly, but it produces more ions per unit of path. A gamma ray is much less efficient as an ionizer since the process is quite different. It does occasionally set free an electron from a molecule by Compton scattering or the photoelectric effect, and this secondary electron has enough energy to produce ionization. A neutron, as we have already mentioned in the text, produces ionization only indirectly by giving high velocity to a nucleus by

elastic collision, or by disrupting a nucleus with resultant ionization by the fragments.

If we are to detect the ionizing effects of these particles, we must evidently use the resultant effect of a great many particles or have very sensitive means of measuring electric currents.

The Electroscope

Essentially the electroscope determines to what degree the air immediately around it has become conducting as the result of the ions produced in it.

The simplest form of electroscope is a strip of gold leaf a few centimeters long, suspended by a hinge from a vertical insulated rod. If the rod is charged, the gold leaf also takes up the same charge and stands out at an angle as a result of the repulsion of like charges. As the charge leaks away, the leaf gradually swings down against the rod, and the rate at which it moves is a measure of the conductivity of the air surrounding it.

A more rugged form of electroscope was devised by C. C. Lauritsen, who substituted a quartz fiber for the gold leaf and used the elasticity of the fiber as the restoring force instead of gravity. The fiber is made conducting by a thin coating of metal. Again the instrument is charged, and the fiber, after initial deflection, gradually comes back to its uncharged position. The position of the fiber is read in a low-power microscope. These instruments can be made portable and rugged and fairly sensitive. They are the standard field instrument for testing the level of gamma radiation, particularly as a safeguard against dangerous exposure.

Ionization Chambers

An ionization chamber measures the total number of ions produced directly in it. It usually consists of two plane electrodes between which there is a strong enough electric field to draw all the ions to the electrodes before they recombine but not strong enough to produce secondary ions as in the instruments we shall describe presently.

By careful design and the use of sensitive amplifiers an ionization chamber can measure a number of ions as low as that produced by a single alpha particle, or it can be used much like an electroscope to measure the total amount of ionizing radiation present instantaneously, or it can be arranged to give the total amount of ionization that has occurred over a period of time.

Proportional Counters

While ionization-chambers can be made which will respond to single alpha particles, it is far more convenient to use a self-amplifying device, that is, to make the ions originally produced make other ions in the same region so that the amplifier circuits need not be so sensitive.

In a proportional counter one of the electrodes is a fine wire along the axis of the second electrode, which is a hollow cylinder. The effect of the wire is to give strong electric field strengths close to it even for relatively small potential differences between it and the other electrode. This strong field quickly accelerates the primary ions formed by the alpha or beta par-

ticle or photon, and these accelerated primary ions (particularly the electrons) in turn form secondary ions in the gas with which the counter is filled so that the total pulse of current is much increased.

It is possible to design and operate such counters in such a way that the total number of ions formed is proportional to the number of primary ions formed. Thus after amplification a current pulse can be seen on an oscilloscope, the height of which will indicate how effective an ionizer the initial particle was. It is quite easy to distinguish in this way between alpha particles and beta particles and photons, and the circuits can be arranged to count only the pulses of greater than a chosen magnitude. Thus a proportional counter can count alpha particles against a background of betas or can even count only the alpha particles having more than a certain energy.

Geiger-Mueller Counters

If the voltage on a proportional counter is raised, there comes a point when the primary ions from a single alpha particle, beta particle, or photon will set off a discharge through the whole counter, not merely multiply the number of primary ions in the region where they are produced. This is a trigger action and the current is independent of the number of ions produced; furthermore, the current would continue indefinitely if no steps were taken to quench it. Quenching can be achieved entirely by arranging the external circuits so that the voltage drops as soon as current passes or by using a mixture of gases in the counter which "poison" the electrode surface as soon as the discharge passes and temporarily prevent the further emission of electrons, or by combining both methods.

The Geiger-Mueller counter was developed before the proportional counter and remains the most sensitive instrument for detecting ionizing radiation, but all it does is "count" any ionizing radiation that passes through it whether it be an alpha particle, proton, electron, or photon.

Art of Counter Measurements

It is one thing to describe the various principles of ionization chambers, counters, and the like; quite another to construct and operate them successfully.

First of all, the walls of the counter chamber must allow the particles to enter the counter. For gamma rays this is a minor problem, but for relatively low-speed electrons or positrons or for alpha particles the walls of the counter must be very thin or there must be thin windows.

Then there are great variations in the details of the counter itself, spacing and size of electrodes, nature of the gas filling the chamber, its pressure, and so on.

Finally, the interpretation of the resultant data is a tricky business. The absorption of the counter walls and of any external absorbers must be taken into account; the geometry of the counter with relation to the source must be estimated to translate observed counts into actual number of nuclear events; last but not always least, statistical fluctuations must be considered since all nuclear reactions are governed by probability laws.

The Wilson Cloud Chamber

There is one method of observing nuclear particles that depends directly on ionization but is not an electrical method. It uses the fact that supersaturated vapor will condense more readily on ions than on neutral molecules. If air saturated with water vapor is cooled by expansion just after an alpha particle has passed through it, tiny drops of water condense on the ions formed by the alpha particle and will reflect a bright light strongly enough to be seen or photographed so that the actual path of the alpha particle is recorded.

This method developed by C. T. R. Wilson in Cambridge, England, about 1912 has been enormously useful in studying the behavior of individual particles, alphas, protons, electrons positrons, mesotrons, photons, and the fast atoms caused by collisions with alphas, protons, or neutrons. Unlike the scintillation method, its companion tool for many years, it has not been superseded and is still used extensively, particularly to study details of collisions between nuclear particles and atoms.

The Photographic Method

The tracks of individual particles passing through matter can also be observed in photographic emulsions, but the lengths of path are so small that they must be observed under a microscope, where they appear as a series of developed grains marking the passage of the particle. This method of observation requires practically no equipment but is tedious and of limited usefulness. It is possible, however, to use the general blackening of a photographic film as a measure of total exposure to radiation, a procedure that has been used to supplement or to replace electroscopes for safety control in many parts of the project.

The Observation and Measurement of Neutrons

None of the methods we have described are directly applicable to neutrons, but all of them are indirectly applicable since neutrons produce ions indirectly. This happens in two ways —by elastic collision and by nuclear reaction. As we have already described, a fast neutron in passing through matter occasionally approaches an atomic nucleus so closely as to impart to it a large amount of momentum and energy according to the laws of elastic collision. The nucleus thereby becomes a high-speed charged particle which will produce ionization in an ionization chamber, counter, or cloud chamber. But if the neutron has low speed, e.g., thermal, the struck nucleus will not get enough energy to cause ionization. If, on the other hand, the neutron is absorbed and the resultant nucleus breaks up with the release of energy, ionization will be produced. Thus, for the detection of high-speed neutrons one has a choice between elastic collisions and nuclear reaction, but for thermal speeds only nuclear reaction will serve.

The reaction most commonly used is the ${}_5B^{10}(n, \alpha){}_3Li^7$ reaction which releases about 2.5 Mev energy shared between the resultant alpha particle and ${}_3Li^7$ nucleus. This is ample to produce ionization. This reaction is used by filling an ionization chamber or proportional counter with boron trifluoride gas so that the reaction

occurs in the region where ionization is wanted; as an alternative the interior of the chamber or counter is lined with boron. The ionization chamber then serves as an instrument to measure overall neutron flux while the proportional counter records numbers of individual neutrons.

One of the most valuable methods of measuring neutron densities by nuclear reactions depends on the production of artificial radioactive nuclei. A foil known to be made radioactive by neutron bombardment is inserted at a point where the neutron intensity is wanted. After a given time it is removed and its activity measured by an electroscope or counter. The degree of activity that has been built up is then a measure of the number of neutrons that have been absorbed. This method has the obvious disadvantage that it does not give an instantaneous response as do the ionization chamber and counter.

One of the most interesting methods developed on the project is to use the fission of uranium as the nuclear reaction for neutron detection. Furthermore, by separating the isotopes, fast and slow neutrons can be differentiated.

Since the probability of a neutron reaction occurring is different for every reaction and for every neutron speed, difficulties of translating counts or current measurements into numbers and speeds of neutrons present are even greater than for other nuclear particles. No one need be surprised if two able investigators give different numbers for supposedly the same nuclear constant. It is only by an intricate series of interlocking experiments carefullly compared and interpreted that the fundamental facts can be untangled from experimental and instrumental variables.

Sweet-Potato Starch Factory

➤ Large-scale commercial production of sweet-potato starch will start next fall, in the newly completed $7,000,000 plant erected at Clewiston, Florida, by the United States Sugar Corporation. Annual output of starch is expected to be 75,000,000 pounds; a valuable byproduct will be 30,000,000 pounds of stock feed from the spent root pulp.

The starch and its derivatives can be used in a wide range of commercial applications, including food products, adhesives, laundry starch, paper and textile sizing, and even explosives.

More than 12,000 acres of rich Everglades soil will be plowed and planted to sweet potatoes. Not all the acreage is owned by the company; part of the crop will be raised under contract by local farmers on their own land. A new sweet-potato variety, bred for this special purpose, has a considerably higher starch content than ordinary table varieties. Individual roots get to be as big as a man's head, and total yield per acre runs from 500 to 700 bushels.

Full operation had been scheduled to begin in 1945, but a hurricane ruined so much of the crop that some delay in starting was unavoidable.

Report on ACS Serum Developed in Russia

Serum Heals Bones, Not Cancer

by Jane Stafford

This survey covers U. S. work on the widely discussed Soviet ACS (anti-reticular cytotoxic serum) preparation which was used by Russian surgeons on the battlefield. Hope that it would prove effective against cancer proves not to be justified, but details of other advances against that condition are reported.

➤ The ACS serum developed by a Soviet scientist has now been given to some 3,500 patients in the United States. The exact figure cannot be given because the final count has not yet been made.

This is the serum you may have read or heard popular accounts of as being able to lengthen human life to 150 years and to cure or prevent a host of diseases such as cancer, arthritis, Hodgkin's disease, infections and mental disease.

ACS is not a cure for cancer. That much can be stated unequivocally, I was told by Dr. Harry Goldblatt, of Western Reserve University School of Medicine, in the course of a search for facts from American scientists who have been studying the serum.

Dr. Goldblatt has prepared the serum and because of "premature publicity and the great demand for it from patients," he has given it to physicians in clinics, hospitals and private practice instead of limiting its use to the relatively few patients he could treat and follow himself. The physicians who were supplied the serum have been sending in their reports and Dr. Goldblatt is now studying them preparatory to publishing the results in a scientific journal.

Besides the fact that the serum does not cure cancer, Dr. Goldblatt has so far found one other fact from the report he is studying. This is that the serum relieves pain in some cases of cancer when pain is the outstanding symptom and has not been relieved by anything else. The pain, however, is the only thing affected. The patients die just the same.

The hope that ACS would cure or prevent cancer and other diseases and lengthen human life seems to have arisen through confusion over the original reports on the subject. Prof. Alexander A. Bogomolets, director of the Institute of Experimental Biology and Pathology, moved from Kief to Ufa during the war, developed the serum which has the full scientific name of anti-reticular cytotoxic serum. He made it by inoculating horses with an extract of the spleen and bone marrow of human cadavers.

Prof. Bogomolets long had been interested in problems of longevity. He believed that the human span should be 125 to 150 years. The life span of other animals is five to six times longer than the period of their maturation, so why should not humans live five to six times longer than the period it takes for them to reach maturity? is the way he reasoned.

Studying human physiology, he came to the view that the physiologic system of the connective tissue is the arena in which disease processes develop. Connective tissue, as its name implies, binds together and supports various structures of the body. The layman recognizes connective tissue in bones and cartilage but it is found in many other structures. According to the modern view, it is not merely a skeleton or framework for body structures but has other functions as well.

In this arena of connective tissue is fought the battle between disease germs and the cells of the body that try to devour the invading germs. The cells that engage in the fight make up another system of the body, called the reticulo-endothelial system. They are found in various parts of the body but are especially abundant in the liver and spleen.

Keeping the system which takes part in the fight to protect the body against disease and injury at a high level of activity is, in Prof. Bogomolets' view, one of the most important problems in treating disease. His anti-reticular cytotoxic serum was designed for this purpose of stimulating the reactivity of this system.

Believing the system fundamental for protection of the body against assault by germs or other disease-causing agents, Prof. Bogomolets believed his stimulating serum might prove effective against a variety of diseases including some that come as the body ages. It might therefore protect against premature death.

This was presented by Prof. Bogomolets as theory, together with the facts of how the serum was prepared and a report that in minute doses the serum stimulated the reticulo-endothelial system while in large doses it had cytotoxic, or cell poisoning, effects on the system.

Unfortunately, Prof. Bogomolets' theory seems to have been reported by others as an accomplished fact. He himself did not claim that the serum had cured cancer or lengthened life. In a report I saw, he wrote that he thought it could do this and perhaps much more. But "could", in the sense of "might be able", is not the same as "does" or "has done".

In this same report it was stated that all work in his laboratory had been directed toward producing enough of the serum to meet the demands of the battlefield where Soviet physicians and surgeons found the serum useful in stimulating wound healing and the union of fractured bones.

Other American scientists besides Dr. Goldblatt have been studying the ACS serum. At the University of Utah School of Medicine Drs. Mark Nickerson, Thomas Burns and Arnold M. Cooper made a serum by injecting rabbits with rat spleen and bone marrow. They then tested its effect in stimulating wound healing.

Up to the present time, skin cuts and broken bones did not heal any faster in animals given the serum than in those without it. However, these scientists do not think their results disprove the stimulating effects of the serum. The reticulo-endothelial system of a healthy animal is probably working at its maximum anyway, Dr. Nickerson pointed out to me, so it is not surprising if it cannot be stimula-

ted further. Tests on animals weakened by chronic infection might show a different result.

At the University of Texas at Galveston, Dr. Charles M. Pomerat and associates Drs. Ludwik Anigstein and Edward H. Frieden, have studied the effect of ACS on cells growing outside the body as well as in the body and have made chemical studies in a search for the chemical nature of the active substance in the serum.

In Los Angeles Dr. Reuben Strauss has found that broken bones produced experimentally in rabbits form stronger calluses, which means they knit better, when ACS is given to the rabbits.

Further News of Cancer

➤ SCIENTISTS may have won two more battles in the war against cancer through discoveries reported by Drs. John J. Bittner Cyrus P. Barnum, Jr., and Robert G. Green, of the University of Minnesota Medical School.

Breast cancer, in mice at least, is apparently caused by a virus transmitted by mother's milk. That is the first discovery.

The second is that this virus can be neutralized by an antiserum. The neutralized virus fails to cause cancer in mice, although the non-neutralized material does.

What this means in terms of human cancer is not yet known but the mouse studies, which have been going on for many years in many laboratories, are of course planned in the hope of finding a solution to the problem of cancer in humans.

First step leading toward the work reported was the discovery by Dr. Bittner 10 years ago that something in the milk of female mice of a cancerous strain was transmitted to their offspring. If the offspring were nursed by females of a strain with low incidence of cancer, the young mice were very unlikely to develop breast cancer.

That cancer-causing something which mice sucked with their mothers' milk has been studied chemically. It is a small-sized molecule that can pass through filters which stop bacteria and other larger molecules. It can propagate itself. It stimulates the formation in rabbits and rats of antibodies against itself. These findings lead scientists to believe the material is a virus.

The antiserum to this virus was prepared by injecting rabbits and rats with mouse cancer tissues that had been centrifuged to concentrate the material. Two weeks after the fifth weekly injection of this material, the blood serum of the rabbits or rats was mixed with cancer cells. The mixture was then injected into mice. None of the mice developed cancer, showing that the cancer-causing agent, or virus, had been completely checked by the antiserum.

Chick Embryo Studies

➤ EVIDENCE to the effect that cancer may be caused by a virus was presented at the American Chemical Society meeting by Prof. Roger J. Williams, director of the Biological Institute of the University of Texas.

First strong indication of a virus cause for cancer was obtained by Dr. Alfred Taylor of the Institute staff who succeeded in inoculating incubating eggs with cancerous material from mice. A filtered extract from these eggs provoked new cancers when injected into healthy mice.

It has been found possible to keep the cancer-cultures going for many months by transplants from egg to egg, and the filtered extracts again caused cancers when re-injected into mice. Something (possibly the virus) emanates from these cancers and produces malignant growth in nearby tissues.

Various methods for separating out this virus, such as low-temperature drying and high-speed centrifuging, have been successful, but not consistently so. The material thus obtained does not always "take".

One highly suggestive result has been the production of cancers in rats from the mouse material, cancers which could not have arisen from the mouse material injected except through the agency of some virus-like cancer-producing agent. Again, however, results were not consistent.

Lack of wholly dependable results is not discouraging the Texas group of researchers. Leads thus far obtained are considered well worth following intensively.

Vitamin Lack

➤ Lack of vitamin B_1, or thiamin, may be the first link in a chain leading via the liver and female hormone to cancer of the uterus, it is suggested in a report by Dr. J. Ernest Ayre and Dr. W. A. G. Bauld, of the Royal Victoria Hospital and McGill University, Montreal, in a recent issue of *Science*.

If the theory proves correct it should be possible, by two simple tests, to determine 1. whether the woman has cancer; 2. if not, whether she is likely to develop cancer; and 3. whether she has a deficiency of thiamin. If the tests show a dangerous precancerous linkage between low vitamin and high female hormone concentrations, prevention of cancer might be possible through corrective treatment.

The vitamin lack might operate to start cancer by damaging the liver, the Canadian investigators suggest. The damage might be too slight to be detected by present tests of liver function, yet might be severe enough to keep the liver from inactivating female hormone. This material might therefore accumulate in the body and cause cancer of the uterus.

Studies of 23 patients plus findings by various scientists from studies of animals gives, the Canadian scientists state, excellent circumstantial evidence to suggest that the nutritional deficiency may have been a primary factor leading to the malignancy.

Penetrating X-rays

➤ Effective penetrating X-ray treatments for cancer and other ills without the patient suffering radiation sickness is possible through the use of a 20,000,000 volt betatron "atom smasher", Dr. D. W. Kerst, professor of physics of the University of Illinois, declared in delivering at the Ohio State University the first of his national Sigma Xi lectures.

With ordinary X-ray machines the distribution of the radiation is different, whereas Dr. Kerst declared with cross-firing with betatron-induced X-

rays it would not be necessary to curtail an X-ray treatment because of radiation sickness produced in a patient.

Dr. Kerst, who is inventor of the betatron, said construction of an atom-smashing betatron of 250,000,000 electron volts would make possible the production of pairs of mesons, atomic particles created hitherto only by cosmic rays from outer space.

A 100,000,000 electron volt betatron at Schenectady, N. Y., has already been used to produce artificially single mesons, but Dr. Kerst explained that if both positive and negative mesons in pairs could be manufactured there would be important opportunities of further exploration of atomic mysteries.

Development of the betatron during the war, Dr. Kerst explained, was concentrated upon types that could take radiographic photographs through more than a foot thickness of steel in order to detect flaws in armor plate and large machinery parts. Using a fast technique, pictures have been taken through 20 inches of steel in 18 minutes.

Plastic from Sugar

➤ Surplus sugar and waste products from sugar factories may be used to make a new plastic molding compound, Dr. Louis Long, of the Massachusetts Institute of Technology, reports to the Sugar Research Foundation. The advantages of sucrose as a plastic raw material, he says, are due to its almost unlimited supply as an inexpensive, very pure organic compound.

Many attempts have been made during the past 15 years to use sugar or its by-products as a raw material for plastic substances, he states. The results to date have been only theoretical because of the sensitivity of the sugar molecule to heat and chemical treatment, causing it to discolor, and because of the difficulty of controlling the polymerization to produce desirable results. A plastic molding compound, however, is already in commercial production on a small scale from bagasse, a waste product from sugar factories.

"Sucrose, and its hydrolysis products glucose and fructose, are potential raw materials," the report states, "for the formation of both colored and colorless plastics of either the phenolic or the alkyd type, the two resins produced in the largest quantity in this country. Sorbitol and mannitol, reduction products of glucose and fructose, should find application as polyhydric alcohols for alkyd resins. Bagasse molding powders are useful in the thermosetting phenolic plastic field."

Rutile is the common name for the titanium dioxide used in welding to form a protective coating and permit the metals to fuse more efficiently; this metallic ore, mined in Arkansas, is used also in making smoke-screen chemicals.

Sizes and Shapes of Molecules Explain Specific Action of Drugs

Molecular Configuration

➤ GREAT ADVANCES in fundamental biology and medicine will come from thorough investigation of the sizes and shapes of molecules of body chemicals and of drugs and germ-killing chemicals, Dr. Linus C. Pauling, director of the Gates and Crellin Laboratories of Chemistry of the California Institute of Technology, declared recently at a meeting of the American Chemistry Society..

Antibodies, substances formed in the body to fight invading disease germs, are protein chemicals with very large molecules, Dr. Pauling pointed out. They react with the antigen of a disease germ or with a protein substance like egg white to form a precipitate in the same way that many of the ordinary precipitates the chemist meets in his work are formed. Dr. Pauling gave as an example the precipitate formed by a solution of a silver salt with a solution containing a cyanide ion. The anti-body-antigen precipitate, moreover, can be redissolved by addition of an excess of antigen just as the silver cyanide can be by an excess of cyanide ion.

The great specificity of interaction between antibodies and antigens is like the formation of a crystal of a substance from a solution, Dr. Pauling pointed out.

After the antigen is injected into the body, antibody molecules are formed in such a way that a region of the antibody takes a configuration that mirrors a portion of the surface of the antigen molecule.

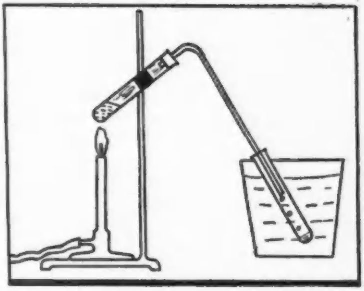
This complementariness in structure leads to a strong attraction between the antibody molecule and the antigen, because it permits this combining region of the antibody molecule to get into close contact with the antigen molecule, Dr. Pauling said. The closer that the two molecules can get in contact with each other, the stronger the intermolecular force of attraction between them.

A crystal of a molecular substance is stable because all of the molecules pile themselves into such a configuration that each molecule is surrounded as closely as possible by other molecules; that is, if a molecule were to be removed from the interior of a crystal, the cavity that it would leave would have very nearly the shape of the molecule itself. Other molecules, with different shape and structure would not fit into this cavity nearly so well, and in consequence other molecules in general would not be incorporated in a growing crystal.

The specific action of drugs and bactericidal substances, he said, has a similar explanation. Even the senses of taste and odor are based upon molecular configuration rather than upon ordinary chemical properties—a molecule which has the same shape as a camphor molecule will smell like camphor even though it may be quite unrelated to camphor chemically.

Pineapple Oil From Butter

by Burton L. Hawk



▶ The chemistry lab has so long been associated with evil smells and acrid vapors that many have lost sight of the fact that the chemist is also capable of reproducing many of nature's more pleasant aromas. The essence of wintergreen, pineapple, apple, pear, banana, grape, etc. are just a few of the many that can be made in the laboratory.

The preparation of essence of pineapple from butter creates an interesting experiment which can be performed rather easily in the home lab. In fact the most difficult part of the experiment is obtaining the butter. If you are one of the fortunate few who has access to a small quantity of the precious substance, and wish to donate it in the interest of science, you may proceed as follows:

Place one teaspoonful of butter in an evaporating dish and heat gently until melted. Now weigh out approximately one gram of potassium carbonate and add it in small portions to the melted butter. It is necessary to stir constantly with a glass rod. Keep your face away from the mixture while heating as the fumes may be somewhat irritating. After the potash has been added, continue to heat the butter to boiling for several minutes. This process is known as *saponification*. Our chief concern with butter here is the glyceryl butyrate content, which we are attempting to extract in the form of potassium butyrate. Most butters contain about two per cent of glyceryl butyrate, which is a compound of butyric acid and glycerin. It has the formula: $C_3H_7.CO.O.$-$CH_2.CH(OH).CH_2OH$.

Our next step is to acidify the butter mixture. After it has boiled for a few minutes, remove it from the flame and add a *small* quantity or dilute sulfuric acid, stirring constantly. Keep adding the acid in small quantities until reaction ceases, which will indicate the solution is acid. The solution should now be distilled. This can most conveniently be done with two test tubes. Pour the butter mixture into one of the tubes, and place a one-hole stopper in it containing a glass tube extending into a second test tube which is immersed in a tumbler of cold water. Heat the butter mixture gently until one-half the mixture distils over. The distillate should now contain a solution of butyric acid. By

adding sulfuric acid to the butyrate salt, butyric acid, being more volatile is set free. It boils at 162°, and condenses in the cool distillate tube. Butyric acid has an unpleasant odor similar to rancid butter.($CH_3.CH_2.CH_2.CO.NH_2.$).

Now add a few ml. of ethyl alcohol to the distillate and an equal quantity of con. sulfuric acid, and distil the mixture once more, being careful not to heat the liquid too strongly. The distillate will contain an appreciable quantity of essence of pineapple which can be easily detected by its odor. It is a welcome product after working with the rancid odor of butyric acid.

Chemically, essence of pineapple is known as ethyl butyrate: $CH_3.CH_2.CH_2.COOC_2H_5$. Pure ethyl butyrate is a colorless liquid boiling at 120° with a specific gravity of 0.879. It is soluble in about 150 parts of water, and is miscible with alcohol, which solution is known as artificial "oil of pineapple".

Now if laughing friends deride, when acrid smoke gets in their eyes, you can take the pineapple oil from the shelf, and prove to them yourself, that the versatile chemist can create sweet soothing savors as well as evil-smelling vapors!

Super-DDT Discovered by British Chemists

➤ A super-DDT, a synthetic compound even deadlier to insects than the original DDT, has been discovered by British chemists. It is known by the convenience-name of Gammexane, and is sometimes referred to by the Apocalyptic number 666. Its exact chemical designation is the gamma isomer of benzene hexachloride.

It is not particularly closely related to DDT in its structural chemistry, but it seems to be even more of a knockout so far as insects are concerned, a report by A. D. Little, Inc., states. By a curious coincidence, its history is like that of DDT in that its existence had been known for a long time, but its insecticidal properties had not been suspected until it was tried out relatively recently. Then it was discovered to be the deadliest weevil poison that the British firm's chemists had ever tested, and it would kill flies in half the concentration required in a DDT solution. It was also proven to be deadlier than DDT to Aedes egypti, the mosquito that carries yellow fever.

There are, however, some points about Gammexane that have not yet been cleared up. It is not known, for example, if it is as persistent under conditions of ordinary use as DDT, which is known to remain toxic to insects for months. Lime, which is used a great deal in agricultural sprays and dusts, is known to be destructive to Gammexane; how to obviate this difficulty has yet to be worked out.

Gammexane is not yet commercially available in the United States, but presumably will eventually appear in the market here.

Bituminous coal is used to heat over 40% of American homes.

**New Ideas of Interest
To the Chemically Minded**

Patented Materials and Processes

THESE IDEAS *are among the newest grist from the Patent Office, which will send the complete patent for 10 cents (not in stamps) if ordered by number from the Commissioner of Patents, Washington 25, D. C.*

➤ WINE-MAKERS of ancient lands, "trampling out the vintage" with purple-stained feet, would stare in gaping amazement at a grape-processing machine on which U. S. patent 2,398,440 has just been issued to Georges Monnet of New York. Its massive mechanism puts on a mass-production basis one of the most ancient of the arts—attributed, indeed, to no less a worthy than Noah.

Grapes brought in boxes from the vineyard to the Monnet machine are dumped upon a copper-screen conveyor and given a thorough washing with jets of water, then passed on through a warm-air drier. From this they go down a second conveyor and through three successive sets of rubber rollers.

The first merely cracks their skins and lets the prime juice trickle out. It is collected in a funnel-like trough, which directs its flow over a chilling coil, to precipitate out impurities, leaving the juice ready either for fermentation or for bottling unfermented. The second and third sets of rollers, set a little tighter, squeeze out second and third grades of juice. The squeezed-out grapes are freed of stems, seeds and skins by mincing with a battery of knives and subsequent centrifuging, which leaves the pulp in condition for marmalade-making or other uses.

Air-Conditioner for Planes

➤ YESTERDAY our fighting pilots flew their planes at 400 miles an hour; tomorrow we shall be riding as passengers at similar speeds. Taking outside air into plane cabins at such a gait is no simple matter of using an open air-scoop, states Waldemar F. Mayer of Los Angeles, in his preamble to patent 2,398,655. At 400-mile speeds, air "rams" and becomes too hot for human comfort. He accordingly places an air-driven turbine in the throat of his air intake, and uses the power thus picked up to drive a refrigerating system which in turn cools the air.

Rights in his patent are assigned to the Garrett Corporation of Los Angeles.

Invisibility by Lighting

➤ WE ORDINARILY throw a bright light on an object when we want it to be easily seen; William D. Cockrell, a General Electric engineer, uses brilliant floodlighting to make ships invisible to possible enemy periscopes. On his paradoxical camouflage system he has obtained patent 2,398,620.

Ships silhouetted against the sky are visible, he explains, because the side toward the observer is usually darker than the sky behind it. Brighten it up to match the sky, and it

virtually disappears. So he suspends floodlights at the ends of long arms, and directs their beams against the ship. The light is made to "match" by means of photocells that "look" first at the ship, then at the sky, keeping the current adjusted by means of suitable amplification and relays.

Rights in the patent are assigned to the General Electric Company.

High-Temperature Alloy

➤ GAS TURBINES, jet engines, rocket units and other new power devices operating at temperatures considered impossible half-a-dozen years ago make severe demands on the metals that have to be exposed to their volcanic breaths. Martin Fleischmann of Canton, Ohio, offers an alloy consisting of 12% to 20% chromium, 4% to 8% molybdenum, a little nickel, a minimum of carbon, and the rest iron. He claims remarkably high strengths for this, at temperatures that would quickly ruin ordinary steels. Rights in the patent, no. 2,398,-702, are assigned to the Timken Roller Bearing Company.

Wet Feathers

➤ EVER NOTICE how wet feathers stick, and tend to clog things up? F. M. Anderson of Duncan, Okla., makes use of this ordinarily annoying property by mixing minced feathers in the "mud" used by oil well drillers to seal off porous layers in the rock through which the well-bore passes. One per cent or less, by weight, turns the trick. Patent 2,398,347 was awarded Mr. Anderson.

Harder Films

➤ ULTRA-THIN metallic films deposited on lenses and prisms to prevent glare and reflection losses can be made harder and more scratch-resistant, states Dean A. Lyon of Washington, D. C., by being laid down from a vaporous state at high temperature in a vacuum. He has obtained patent 2,-398,382 on his method.

Large Plastic Pipe

➤ LARGE-DIAMETER pipe of corrosion-resistant plastic, cheaper than comparable tubing made of special alloy metals, can be formed by a new continuous-strip wrapping process.

U.S. patent 2,398,876 on this process has just been issued here to James Bailey of West Hartford, Conn.

Polystyrene or similar material is extruded hot through a slit, and immediately wound on a group of rollers arranged in a six- or eight-sided, slightly conical pattern. As the strip makes edge-to-edge contact it spontaneously fuses together. The material is sufficiently stretched so that it will contract as it slides off the group of rollers, automatically assuming a cylindrical shape.

This method makes it possible to form the tubing in any desired length, doing away with the rigid limits to length involved in forming tubing over mandrels; also, it obviates the frequently considerable difficulty in getting the sticky stuff off the mandrel. Patent rights are assigned to the Plax Corporation, of Hartford.

Magnets Without Iron

➤ MAGNETS, to most persons, imply iron or steel; but some of the most useful permanent magnets are made without any ferrous metal at all, consisting mainly of silver, with from 2% to 8% aluminum and 5% to 15% manganese. Goodwin H. Howe, of Menands, N.Y., has taken out two

patents, nos. 2,399,031 and 2,399,032, on a method for improving the magnetic properties of this alloy. Cast in three-quarter-inch rods, it is first heat-treated at 760 degrees Centigrade, then cold-swaged to a smaller diameter. Patent rights are assigned to the General Electric Company.

Aluminum-Beryllium Alloy

➤ A NEW ALLOY combining the lightness of aluminum with the stiffness, hardness and corrosion resistance of beryllium is covered by patent 2,399,-104, issued to Hugh S. Cooper of Cleveland and assigned by him to Cooper-Wilford Beryllium, Ltd., of Philadelphia. The two metals are melted together in a crucible under a calcium chloride flux. As they slowly cool, a little silver-sodium alloy is added. The silver enters the aluminum-beryllium alloy, adding to its hardness; the sodium serves mainly as a scavenger element to clean out remaining impurities.

Super-High-Speed Vehicle

➤ A SUPER-HIGH-SPEED amphibious vehicle, which defies the slowing-down drag of skin friction as it tears over the water, is described by an English inventor, R. M. Hamilton, of Churt, Farnham, in patent 2,399,021. A wide, belt-like tractor surface passes around the entire hull or body of the vehicle. It is provided with short feathering paddles of rubber or similar material, which thrust the water backward, overcoming skin friction. The vessel tends to "climb," says the inventor, raising its forward end clear of the water and thus appreciably diminishing its displacement.

Floating Soaps

➤ FLOATING SOAPS float for the same reason that a steel ship floats; they contain air. To mix air into the soap mass more effectively, in the form of microscopic bubbles, John W. Bodman of Winchester, Mass., has invented a machine on which he has received patent 2,398,776. Patent rights are assigned to Lever Brothers Company.

Rubber Plating

➤ RUBBER would be an ideal protective covering for metals—only the two ordinarily won't stick together. To make "rubber-plating" more secure, H. W. Grinter of Cuyahoga Falls, N. Y., and M. E. Gross of Akron, Ohio, propose to prepare the metal surface by first producing a dark sulfide layer on it, preferably by exposing it to hydrogen sulfide. Then the rubber is spread on, and vulcanized under pressure. Rights in patent 2,399,019, issued on this method, are assigned to the B. F. Goodrich Company.

Saving SO_2

➤ SULFUR DIOXIDE, valuable as a bleaching gas and for other industrial uses, can be salvaged from smelter fumes, flue gases, etc., by first running the mixed gases through a selective organic absorbent, such as anhydrous dimethyl amide, then freeing it by heating. On a method that involves less use of heat from outside sources, E. P. Fleming of Los Angeles and T. C. Fitt of Salt Lake City have been granted patent 2,399,013, rights in which are assigned to the American Smelting and Refining Company.

Bazooka Increases Oil

➤ THE SAME KIND of explosive setup that made the little rockets of the bazooka a terror to tanks during the war is adapted for use in boosting oil production, in a new invention on which U.S. patent 2,399,211 has just been issued here to two duPont research scientists, Dr. C. O. Davis and Dr. L. A. Burrows, both of Woodbury, N.J.

For some years it has been regular practice to lower specially built, short-barreled guns into oil wells, to shoot holes through the casings at oil-bearing levels, thus letting the oil flow into the wells. Loaded with ordinary powder, these guns do not have very high penetrating power.

Drs. Davis and Burrows substituted hollow-nosed charges of the super-high explosive called pentolite for these short-barreled guns. When a hollow charge is exploded, an intensely hard, piercing tongue of flame spurts out, in what is known as the Munroe effect. This was what gave the bazooka projectiles their armor-piercing power, and it is also utilized in the new casing perforator. A metal lining of the hollow charge becomes a projectile when it is exploded, adding to the depth of penetration, and hence to the freer flow of the oil.

Patent rights are assigned to E. I. duPont de Nemours and Company.

Compact Flash-Lamp

➤ AN IMPROVED FLASH-LAMP for use in the millionth-second, super-speed photography used for "freezing" whirling machinery and other fast motion is offered for patent no. 2,399,222 by one of the pioneers of this kind of illumination, Kenneth J. Germeshausen of Newton Center, Mass. The long gas-filled tube that produces the light is contracted into a helical coil for compactness and covered with an outer bulb or envelope for safety in handling. The flash charge is built up in it, and set off by a trigger coil that loops over the turns on one side of the helix.

Chemical Potato Peeling

➤ KITCHEN POLICE should hold no terrors for tomorrow's recruits, if the Army sees fit to adopt the chemical potato-peeling method on which R. W. Miller and O. W. Andrews of Barberton, Ohio, received patent 2,399,282. The potatoes are plunged into a nearly boiling solution of caustic soda, salt and sodium chlorate, which loosens the skin so completely that subsequent rinsing in water easily washes it away. Rights in the patent are assigned to the Pittsburgh Plate Glass Company.

Mineral Wool

➤ A CENTRIFUGAL mineral-wool-making apparatus is covered by patent 2,399,383, granted to E. R. Powell of North Plainfield, N. J. and assigned by him to the Johns-Manville Corporation. A thin stream of slag, glass or other molten material is flowed onto a rapidly spinning rotor, which throws it off in the form of fine threads that harden immediately. A jet of binder adhesive is blown into the flying mineral spray.

Beryllium

➤ AN ARGENTINE INVENTOR, Maxime H. Furlaud of Buenos Aires, has received patent 2,399,178 on a method for winning the valuable light metal beryllium from its ores. Key to his process is the use of ammonium fluoride as a differential solvent.

Aluminum Protection

➤ CORROSION of aluminum is held in check by the addition of less than 1% of amyl stearate to gasoline in airplane fuel tanks exposed to risk of attack by salt water. Patent 2,396,236, issued on this discovery to E. L. Baldeschwieler of Cranford, N. J., and J. C. Zimmer of Union, N. J., is assigned to the Standard Oil Development Company.

Fine Powders from Dried Spray

➤ AN INGENIOUS METHOD for getting very finely powdered chemicals, each grain consisting of an individual crystal, is represented in patent 2,396,689, taken out by C. P. Davis of Stamford, Conn., assignor to the American Cyanamid Company. In this device, the chemical in solution is projected as a fine spray from the edge of a rapidly spinning wheel. The spray meets a counter-flowing current of warm air, which evaporates the water, until the chemical forms crystals that fall into a collector at the bottom.

Arachnicide

➤ BECAUSE POISONS effective against insects are not always useful against ticks, mites and other small but troublesome members of the spider tribe, William P. ter Horst of Pompton Plains, N. J., has developed a special chemical for their elimination, which he calls an arachnicide—the spider group are known to zoologists as arachnids. The chemical name of Mr. ter Horst's arachnicide is N-isopropylidene-p-ethoxy-aniline. Rights on patent 2,397,633, covering this invention, have been assigned to the United States Rubber Company.

Heat-Absorbing Glass

➤ FORMULA for a heat-absorbing glass is the subject of patent 2,397.195, taken out by G. C. Mook and R. W. Ricker of Toledo, Ohio, assignors to the Libbey-Owens-Ford Glass Company. Principal constituents are sand, limestone and soda ash; smaller quantities of salt cake, powdered charcoal, borax, fluorspar and iron oxide are added.

Electroplated Ball Bearings

➤ STEEL BALLS for ball bearings can be electroplated with protective metals in the apparatus on which Richard M. Wick of Allentown, Pa., has obtained patent 2,397,177. The balls are placed in the electrolytic bath which is contained in the annular space between two cylinders. They are kept moving throughout the treatment by magnetic means within the inner cylinder, holding them against its outside by attraction through the wall.

Life-Saving Rocket

➤ A PISTOL-FIRED rocket, to carry a parachute flare or a life-line, is the invention on which Ralph Anzalone of Oceanside, N. Y., has been granted patent 2,397,114. The rocket is set in the muzzle of the large-caliber pistol and thrown into the air for some distance by a light powder charge. Then its own propellent charge ignites, and it ceases to be a bullet and becomes a rocket.

Sweden expects, by reducing the cost of charcoal by collecting and selling all byproducts, to produce a fuel for its charcoal burning producer-gas automobile engines that will be at least as cheap as imported gasoline.

It's the Law!

➤ SOMEBODY'S LAW needs to be invoked in each of the following cases. Can you tell whose? and state the Law? and give some facts about the author of it? If not, you are sentenced to banishment to page 49.

1. You have a liter of gas at room temperature which you want to heat to 100° C., keeping the pressure the same. Whose law will you use to find how big a container you will need?

2. You want to know the volume of a certain gas at 20°C. Whose law will you use to find it for sea-level and for the top of a mountain a mile high?

3. You want to combine a liter of hydrogen with a volume of chlorine gas to form HCl. Whose law will tell you how much chlorine you should use?

4. Into a given container filled with air you want to introduce an equal volume of carbon dioxide. Whose law will tell you what effect the new gas will have on the pressure in the container?

5. You are running two electroplating baths, using the same current but twice as concentrated a solution for one as for the other. Whose law will tell you what the difference will be in the amount of metal deposited?

6. You are measuring the diffusion rates of two gases. The density of one gas is twice that of the other. Whose law will tell you which will diffuse faster, and by how much?

7. You are studying the effect that non-ionizing compounds have on the freezing and boiling points of water when they are dissolved in it. Whose law will give you the rule by which this effect can be calculated for different compounds?

8. You are about to start a reaction from which it is possible to get either of two different products, under different conditions. By whose law can you calculate the proper conditions for the product you want?

9. If you keep the temperature and pressure constant, what other factor in a chemical solution can you vary? The formula you will use to make calculations for the results as you vary these factors is written:

$$F = C + 2 - P$$

If C stands for the number of components of a system in chemical equilibrium and P stands for the number of mechanically separable and physically distinct portions of the system, such as gases, solutions or crystalline states, what does F stand for? Who discovered this relationship?

If you have had a year of chemistry, you ought to know three of these laws. An upper classman specializing in chemistry might be expected to know six. If you are a chemical engineer in charge of operations, you may have to use them all. But cheer up! We learned a lot by looking them up in handbooks and encyclopedias, too.

Raised for Laboratory Use
Pests Grow Bigger and Better

Flies Test Insecticides

by Dr. Frank Thone

➤ Isn't it odd, how the fly has joined the bee as a domesticated insect!

For centuries, the honeybee was the only insect that could be counted among man's domestic animals. To be sure, the bee was somewhat less domestic even than the goat: it would consent to live in quarters provided by man, and would yield up part of its product to him under rather drastic persuasion. But the fly remained wholly wild and free, living in man's houses as a tolerated pest, as rats and mice do.

➤ Predestined flies, *raised tough so they will be harder to kill. The number of flies killed measures the strength of the insecticide being used.*

Only when the fly finally became recognized as a disease-carrying pest that could no longer be tolerated did man take the trouble to domesticate it. Nowadays, in a considerable number of places, flies are solicitously reared on selected food in large, sanitary cages. Special care is given to insure maximum reproduction, and growth to healthy maturity of the insects that emerge after pupation.

This procedure, which a couple of generations ago would have been regarded as sheer lunacy, is carried out in order to secure adequate stocks of flies on which to test the potency of insecticide sprays. When a new batch of spray is ready, a counted number of flies are released into a windowed test chamber. The spray is released under uniform pressure through standardized nozzles.

By tens and fifties the victims fall, while the entomologists coolly watch the slaughter through the window. After a stated time period they count the survivors. If these number more than a certain maximum percent, the batch of spray is rejected as too weak. If the "knockdown" number is high enough, and the eventual kill is also high, the spray receives the official OK.

This business of wholesale production of flies for the insecticide testing laboratories has been going on not quite a quarter-century. When the first domestic fly sprays were produced, back in the early '20s, the winged guinea pigs needed to assay their deadliness had to be captured in the wild—usually in the rear of livery stables that still survived at that time.

Soon, however, this haphazard source proved insufficient. It was inadequate qualitatively as well as quantitatively, for comparative tests showed that "wild" flies from the dungheap were not as strong and tough as those hand-raised on more carefully selected foods, and hence not as good test animals. Oddly enough, it was found that the best fly food is milk. Milk-fed flies are quite the opposite of tender; in Flydom, "milksop" means "toughie."

Vitamin A, Good for Young and Old

➤ Increasing the family's vitamin A consumption is good for young and old, it appears from studies of rats reported by Dr. H. C. Sherman and Dr. H. L. Campbell, of Columbia University, to the National Academy of Sciences.

Liberal intake of this vitamin, found in such foods as butter, liver, egg yolk, carrots and green leafy vegetables, tends to postpone aging and increase length of life, Dr. Sherman and colleagues have previously reported.

Now they find that the offspring in rat families on the liberal vitamin A intake grow somewhat more rapidly and with less individual variability. This indicates, the scientists point out, that liberal vitamin A has both a favorable and a stabilizing influence on growth.

This favorable, stabilizing effect on rat growth was observed with vitamin A intakes two and four times higher than the intake considered fully enough to meet the rat's nutritional needs.

Chemical Magic

Little Straw Water 'Beetles'

by Joseph H. Kraus

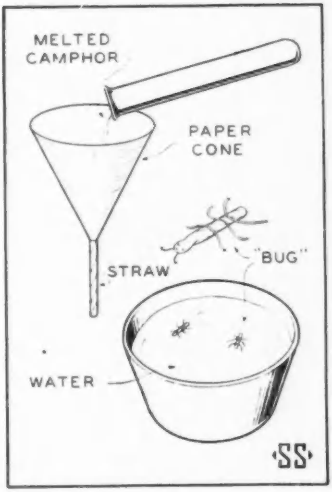
• Curious little imitation bugs and beetles that will dart about the surface of a bowl of water can be made by cementing straw legs to a one-inch length of paper drinking straw filled with camphor.

The front of the straw is pinched close so that only in the rear does water come into contact with the straw. The straws are caused to move forward by the camphor in the straw which changes the surface tension of the water immediately to the rear of the paper tube.

To make the "water beetles," cut an ordinary paper drinking straw into short lengths varying from one-half to one-and-a-half inches. Pinch one end together between your fingernails. Using either a test tube or a small iron frying pan, melt some lump camphor over a low flame. You can get the camphor either at the drug store or in the 5- and 10-cent store.

When melting the camphor, have a metal cover handy so that in case it catches fire, you can quickly snuff out the flame. Do not let the camphor burn for it produces a dense black soot.

Hold one of the short lengths of drinking straw in a vertical position with a pair of pliers or tweezers. Over the open end of the straw hold a paper cone or a paper drinking cup, the tip of which has been cut off. Now pour a minute quantity of camphor into your makeshift funnel. Only



a little is needed to fill the short length of straw.

Dress-Up the "Bug"

To convert your short length of straw into a "bug," mark a pair of eyes on the closed, pinched end, and attach two small pieces of broom straw or excelsior to represent antennae. Lay three pieces of excelsior or broom straw across the body and secure them with tiny drops of celluloid cement. Holding the bug flat on the table top, pinch the straws down over the body and press them with your fingernail to flatten the legs. Make a number of straw bugs of different sizes in this way.

Now fill a white enamel pan or bowl with clean, cold water. To remove any grease that might be on the surface, tear off a sheet of newspaper about the size of the surface and float it on the water. With grease-free fingers, pick up the floating newspaper by one corner and gently lift the paper, dragging it across the surface. When you drop the straw bugs into the water, they will dart about the surface.

Whenever the bugs hit an edge of the bowl, turn them around so they can start traveling in another direction. When they finally stop moving, which will probably occur in about a half hour, carefully lift the bugs out of the water and again clean the surface with a clean paper. Now the bugs can make another trip.

With the naked eye it is difficult to see the almost invisible stream of water, exuding from the rear of the straw, that causes the bugs to move forward. You can see it, however, by glancing at the shadow of the straw bug cast on the bottom of the white enamel bowl. Hold the bowl under an electric light and notice the bulb-like irregular shadow beyond the tail of the bug and around the straw wherever you accidentally spilled a little camphor.

Chemical Curiosity and Diagnostic Drudge

➤ IMMUNITY to disease is intensified by a substance in blood known as complement, which is a chemical curiosity and a diagnostic drudge, Prof. Michael Heidelberger, of Columbia University, explained in his national Sigma Xi lecture delivered in many localities throughout the nation.

"Freshly drawn blood is an extraordinarily complicated and unstable conglomeration of cells and dissolved materials," he said. "After it clots, the clear serum which may be drawn off is found to have unusual properties. These are ascribed to complement, or alexin, an unstable complex of serum constituents. Complement is removed from the serum by many immune reactions; that is, in the combination between antigens and antibodies.

"Antigens are foreign substances or particles such as bacteria, which penetrate to the body fluids and tissues and stimulate the system's defense mechanism to produce other substances known as antibodies. Antibodies are able to combine specifically and selectively with the antigen giving rise to their stimulation.

"When this defense mechanism of the body has begun to act on invading micro-organisms and the antibodies have combined with the disease-producing cells, complement often swings into action by actually dissolving the germ-antibody complex or by speeding up its disposal and digestion by the scavenger white cells, or leucocytes, of the blood.

"Similarly, complement causes solution (hemolysis) of red blood cells which have combined with antibodies. On this behavior are based diagnostic tests, such as the Bordet-Wassermann reaction, which are used on a vast scale all over the world as a test for syphilis. Another such 'complement fixation' test is useful in the study of virus diseases, such as influenza. One has limited application in malaria."

U. S. Chemists More Than Held Own In Industrial War With Germany

German War-Time Chemistry

➤ GERMAN CHEMISTS had the better of American chemists on some fronts in the industrial war behind the shooting war. But they were not supermen; American chemists more than held their own in other fields.

This reversal of the state of affairs that obtained during World War I, when German chemical industry was triumphant all along the line, was described by R. L. Murray, Vice-president of the Hooker Electrochemical Company at Niagara Falls, N. Y., to the American Chemical Society. Mr. Murray was one of the American technical men who investigated German chemical plants after the close of the war.

One field in which German scientists had made tremendous advances, he reported, was the production and use of acetylene, valuable in itself as an industrial gas and also as initial raw material for certain types of synthetic rubber and many other products. Calcium carbide, from which acetylene is generated by the addition of water, is made from coal and limestone. The Germans produced this compound almost as fast as we did, and they developed means for the safe handling of acetylene at higher pressures than we used, which made possible the synthesis of many materials hitherto considered impossible.

Lacking fats and oils for the production of glycerin, the Germans made this war-necessary liquid out of two materials they did have: sugar and the gas propylene. This was a feat done under the lash of necessity, however, Mr. Murray commented; it is doubtful whether either of these processes could compete with American methods of glycerin production from fats.

In drugs and related compounds, he continued, German accomplishments were great. But no greater than those of American applied science. Penicillin production in Germany, for example, was insignificant, whereas it was on a highly successful mass-production basis in this country. And the Germans lagged far behind in the field of synthetic rubber.

If the German technologists could not make a synthetic "stay stuck" at ordinary temperatures and pressures, they raised both until they got what they wanted. Some of their pressure vessels were built like big naval guns: a liner or inner tube, surrounded with interlocking hoops to take up most of the strain.

Fuel Gas From Coal

➤ WITH NO OIL at their disposal but plenty of coal, German chemists did remarkable things with the solid black fuel, especially under wartime pressure. Latest disclosure of German coal-chemical secrets was made to the American Chemical Society meeting at Atlantic City by Dr. H. M. Weir of Philadelphia, who had experience in German plants before the war.

The Germans succeeded in raising to a new level of efficiency one of the oldest coal-extraction processes, the gaining of fuel gas by the heating of coal. Instead of loading the coal into kilns in batches and then heating it up in the traditional way, Dr. Weir said, the German chemical engineers devised a continuous process, in which coal was kept in a constantly incandescent state in thick fuel beds, from six to 12 feet deep, which were played on by streams of oxygen and steam. The whole process was carried on under a pressure of about 360 pounds per square inch. The resulting gas was a mixture consisting mainly of hydrogen, carbon monoxide and methane.

American Wartime Reagents

➤ QUALITY as well as quantity marked American wartime production of chemical reagents, according to Dr. G. E. F. Lundell, chief chemist of the National Bureau of Standards.

Despite the stress of war, Dr. Lundell said that Bureau of Standards tests had shown a smaller percentage of substandard chemicals during the four war years than in any previous period of years since the tests were started more than 20 years ago.

During the war years, 1941-45, he reported that 87% of the reagents tested were fully acceptable, with only 6% significantly below specifications.

This, Dr. Lundell pointed out, was in sharp contrast to the record during World War I, when American chemists became wholly dependent on domestic production of reagents for the first time.

During the late twenties, he said, a survey over a two-and-one-half year period found only 65% of the chemicals tested to be acceptable, while 26% were definitely substandard.

For the four years before World War II, the Bureau found 86% acceptable and 8% markedly below the line.

Thus, Dr. Lundell said that American production of chemical reagents actually improved in quality during the war despite the acceleration of production to meet war demands.

Blood Plasma Fired in Artillery Shells

➤ BLOOD PLASMA was successfully fired in artillery shells to Allied troops cut off by Nazis in Europe, reports Maj. General Paul R. Hawley, surgeon to the European Theater of Operations, in a report appearing in the Marine Corps Gazette. This adds a new item to the list of many ways in which blood plasma has been delivered to American fighting men. In the past, plasma has gone to the front by plane, ship, on horseback and in jeeps, and it has been dropped from the air in parachutes.

Gen. Hawley reports that pre-invasion estimates of the amount of plasma that would be required to fill the needs of the Army were far too low. Instead of one transfusion required for every five men wounded, battle experience has shown the need for one transfusion for every two men wounded.

Gold Transformed to Mercury Provides New Measurement Standard

Alchemists' Dream in Reverse

➤ BY THE TRANSMUTATION of gold into mercury in the cyclotron—a reversal of the alchemists' dream—University of California scientists have produced a standard for the measurement of length which is proving itself to be ten times as accurate as the one now accepted.

The standard for measurement is a spectrum line—at present a red light ray produced by making the atoms of cadmium glow.

The new standard is a sharp green light ray produced by exciting the atoms of the transmuted mercury in a quartz tube with a high frequency radio beam until they give light.

Measurements can be made with the green light ray with an accuracy of billionths of an inch. The standard of measurement is used in the grinding of lenses and prisms, in the testing of nearly all optical equipment, and in a vast number of scientific experiments requiring precise measurements.

The special type of mercury made from gold is the isotope, or "sister," in the mercury family with the atomic weight 198. It is produced by bombarding gold atoms with neutrons. The gold atoms "capture" neutrons, becoming radioactive, and, after emitting electrons, turning into mercury 198.

Ordinary mercury has a number of isotopes, and when it is made to glow each isotope emits a slightly different light, much as there are a number of different notes in a chord played on a piano. A spectroscope separates the light into its component parts.

Gold is transmuted into mercury 198 of such purity that less than one atom in a million is other than mercury 198. Therefore the sharp green line of mercury 198 is produced with great clarity and sharpness, undiluted by the light of other mercury isotopes, much as a single note on a piano is struck. Its wave length does not vary by more than one fifty-billionth of an inch.

About five milligrams—half a cent's worth—of gold is used in the transmutation of enough mercury to make a "lamp" for the mercury measurement standard. The Berkeley scientists estimate that hundreds of thousands of times as much mercury 198 could be produced by using the "pile" technique used in the atomic bomb project as can be produced in cyclotron bombardment.

The superiority of the mercury measurement to that of cadmium is due partially to the fact that mercury atoms are heavier and can be made to glow at temperatures below freezing. Heat makes atoms move faster, and lighter atoms move more than heavy ones. The lightness of cadmium atoms plus the fact that they must be

heated to 300 degrees centigrade to produce the red light ray result in a fuzzier line than the mercury ray.

The cadmium standard of length was adopted in 1893 as the primary standard of length, and had not been improved on until the mercury ray was produced. The Berkeley scientists believe it will be possible to produce a mercury "lamp" which can be plugged into a 110 volt alternating current outlet. This is much simpler than the cadmium equipment, which requires a furnace.

Mercury for a dozen lamps has been produced in cyclotron bombardments. Several lamps have been sent to the Bureau of Standards for experimentation, some have been sent to the Eastman Kodak Company, while others are used in university laboratories.

Transmutation of gold into mercury 198 was accomplished by Dr. Jacob H. Wiens, now a staff engineer of the U. S. Electronics Research Laboratory on the Berkeley campus, and Dr. Luis Alvarez, professor of physics and one of the nation's leading young atomic scientists.

Atomic Bomb a U. S. Headache

➤ The atomic bomb was pictured as a disturbing element, in the most literal sense of the word, so far as America's world relations are concerned, in an address by Prof. Harold Urey of the University of Chicago, one of the top group of scientists who fathered the destructive monster.

The Russians are very much upset over the present American monopoly position in the atomic energy field, he pointed out. Present lack of atomic weapons, they feel, directly injures Soviet prestige, and their feelings are further lacerated by the often-heard boast that the United States is so far ahead that no other nation can catch up. To this must be added the fear, always close to the surface, that the "outside" capitalistic world may attempt a war of aggression against the USSR.

In Britain, Prof. Urey said, there is great anxiety over the American policy with respect to the atomic bomb, and a strong feeling that the whole business should be subject to international control. So far as a possible atomic war is concerned, Britons see their country as a much more concentrated industrial target than the United States for long-range atomic weapons, just as it was for the relatively primitive V-bombs of the recent war.

If it came to an atomic war between the USSR and the USA, the speaker continued, we would be the worse off, once the USSR possessed atomic weapons. We are a far more highly urbanized people than the Russians, and the giant industries of which we are so proud would be, along with our cities and seaports, just so many tempting targets. We might attempt dispersal, but in a democracy the decision would be hard to arrive at and so slow in execution that we might well be overwhelmed before it could be carried out.

Answers to Chem Quiz on Page 40

1. Gay-Lussac's Law: The volumes assumed by a given mass of a gas at different temperatures, the pressure remaining constant, are directly proportional to the corresponding absolute temperatures. (This is sometimes known as Charles' law, on authority of a quotation by Gay-Lussac.) Joseph Louis Gay-Lussac (1778-1850) was Professor of Chemistry at the Sorbonne, Paris.

2. Boyle's Law: The volume occupied by a given mass of any gas at constant temperature varies inversely as the pressure to which it is subjected. Robert Boyle (1627-1691), son of the Earl of Cork, was one of the founders of the Royal Society.

3. Avogadro's Law: Under the same conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules. The numerical value comes out at 6.06 x 10^{23} molecules per mole. Amedeo Avogadro (1776-1851), Conte di Quaregna, was Professor of Physics at Turin University.

4. Dalton's Law: The pressure exerted by each component in a gaseous mixture is independent of other gases in the mixture, and the total pressure of the mixture of gases is equal to the sum of the pressures of the separate components. John Dalton (1766-1844), who is credited with introducing the concept of the atom into modern chemistry, was a teacher at New College, Manchester, England.

5. Faraday's Law: In the process of electrolytic changes equal quantities of electricity charge or discharge equivalent quantities of ions at each electrode. Michael Faraday (1791-1867), who gave us so many discoveries in electricity, was lecturer at the Royal Institution, London.

6. Graham's Law: The relative rates of diffusion of gases under the same conditions are inversely proportional to the square roots of the densities of those gases. Thomas Graham (1805-1869), Professor of Chemistry at University College, London, succeeded Sir John Herschel as Master of the Mint.

7. Raoult's Law: Molar weights of non-volatile non-electrolytes dissolved in a definite weight of a given solvent under the same conditions lower the solvent's freezing point, elevate its boiling point and reduce its vapor pressure equally for all such solutes. François Marie Raoult (1830-1901) was Professor of Chemistry at Grenoble, France.

8. Van't Hoff's Law: If the temperature of interacting substances in equilibrium is raised, the equilibrium concentrations of the reaction are changed so that the products of that reaction which absorb heat are increased in quantity, or, if the temperature is lowered, products which evolve heat are increased. Jacobus Hendricus van't Hoff (1852-1911), Dutch chemist, was a Professor at the University of Berlin.

9. Gibbs' Phase Rule: F stands for the number of degrees of freedom of temperature, pressure and concentration which fix the system. Josiah Willard Gibbs (1839-1903) was Professor of Physics at Yale.

The State Department Report
Plan for Atomic Energy Use

International Atomic Control

In this, the third part of the Report of the State Department's Committee on Atomic Energy, prepared by its Board of Consultants who are experts on the problems involved, the way out of the difficulties of nationalism is clearly shown. The concluding portion will appear in CHEMISTRY *for July.*

The Report considers the factors to be taken into account in any plan to control atomic energy development. It concludes that "an otherwise uncontrolled exploitation of atomic energy by national governments will not be an adequate safeguard." While inspection of operations will be necessary, the controlling agency, in the opinion of these experts, "must itself be active in research and development, and well informed on what is an essentially living art."

Security Through International Cooperative Development

IN THE PRECEDING sections of this report we have outlined the course of our thinking in an endeavor to find a solution to the problems thrust upon the nations of the world by the development of the atomic bomb—the problem of how to obtain security against atomic warfare, and relief from the terrible fear which can do so much to engender the very thing feared.

As a result of our thinking and discussions we have concluded that it would be unrealistic to place reliance on a simple agreement among nations to outlaw the use of atomic weapons in war. We have concluded that an attempt to give body to such a system of agreements through international inspection holds no promise of adequate security.

And so we have turned from mere policing and inspection by an international authority to a program of affirmative action, of aggressive development by such a body. This plan we believe holds hope for the solution of the problem of the atomic bomb. We are even sustained by the hope that it may contain seeds which will in time grow into that cooperation between nations which may bring an end to all war.

The program we propose will undoubtedly arouse skepticism when it is first considered. It did among us, but thought and discussion have converted us.

It may seem too idealistic. It seems time we endeavor to bring some of our expressed ideals into being.

It may seem too radical, too advanced, too much beyond human experience. All these terms apply with peculiar fitness to the atomic bomb.

In considering the plan, as inevitable doubts arise as to its acceptability, one should ask oneself "What are the alternatives?". We have, and we find no tolerable answer.

The following pages contain first a brief summary of the plan we recommend, and then an expansion going into some detail.

Summary of Proposed Plan

The proposal contemplates an international agency conducting all intrinsically dangerous operations in the nuclear field, with individual nations and their citizens free to conduct, under license and a minimum of inspection, all non-dangerous, or safe, operations.

The international agency might take any one of several forms, such as a UNO Commission, or an international corporation or authority. We shall refer to it as Atomic Development Authority. It must have authority to own and lease property, and to carry on mining, manufacturing, research, licensing, inspecting, selling, or any other necessary operations.

This chapter is not an attempt to write a corporate charter for such an international agency. It is the aim, rather, to show that such a charter can be written in workable terms, and that the nature of the organization and its functions will have decisive consequence for world security. We are satisfied that the differences between national and international operations can be exploited to make the problem of atomic energy manageable. This idea, we think, can become as familiar as the fact that the differences between individual enterprise and corporate enterprise have important consequences in the conduct of business.

If we are to do anything constructive in relation to atomic energy it must inevitably be novel and immensely difficult. We think that the weeks that we have spent in analysis of the problem have made it appear somewhat less difficult and somewhat less novel. A succession of such processes will be necessary, each building on the preceding analysis, before even the major ramifications of the problem can be understood and the major questions partially answered. What is chiefly important now is to describe the right course of action in terms sufficiently practical and valid to show that the further exploration is worthwhile.

The proposal contemplates an international agency with exclusive jurisdiction to conduct all intrinsically dangerous operations in the field. This means all activities relating to raw materials, the construction and operation of production plants, and the conduct of research in explosives. The large field of non-dangerous and relatively non-dangerous activities would be left in national hands. These would consist of all activities in the field of research (except on explosives) and the construction and operation of non-dangerous power-producing piles. National activities in these fields would be subject to moderate controls by the international agency, exercised through licensing, rules and regulations, collaboration on design, and the like. The international agency would

also maintain inspection facilities to assure that illicit operations were not occurring, primarily in the exploitation of raw materials. It would be a further function of the Atomic Development Authority continually to reexamine the boundary between dangerous and non-dangerous activities. For it must be recognized that although the field is subject to reasonable division, the dividing line is not sharp and may shift from time to time in either direction.

The development agency itself would be truly international in character. Its staff would be recruited on an international basis. Its functions would be such as to attract a calibre of personnel comparable to our own activities in raw materials during the war and our own primary production and experimental work. It would be set up as one of the subsidiary agencies of the United Nations, but it would have to be created by a convention or charter establishing its policies, functions, and authority in comprehensive terms.

Whatever the formal organization, its integration with national structure would of course be one of the major problems. Measures to assure the proper degree of accountability to the United Nations and to individual nations, measures to assure that individual nations would have ample opportunity to be informed of the agency's activities, measures to make the agency responsive to the changing needs of nations—all these would have to be worked out with extraordinary care and ingenuity. But certainly our experience with business and government institutions, national and international, would afford a wealth of guidance in the development of such measures.

In the actual conduct of its operations the development organization would at all times be governed by a dual purpose, the promotion of the beneficial use of atomic energy and the maintenance of security. We believe that much can be done in a convention or charter to make these purposes concrete and explicit, to draw the line between the dangerous and the non-dangerous, to establish the principles determining the location of stockpiles and plants so that a strategic balance may be maintained among nations, to establish fair and equitable financial policies so that the contributions of nations to, and their receipt of benefits from the organization will be justly apportioned. The most careful and ingenious definitions will be required in order to accomplish these purposes.

In what follows we shall attempt to develop and expand the foregoing statement of essentials.

We can best visualize the Atomic Development Authority in terms of the answer to these concrete questions:

(1) What will be the functions of the agency; what are the things that it will do?

(2) What kind of organization is necessary to carry out these functions?

(3) How will the organization be related to the United Nations and the individual nations that it will represent?

(4) What policies will guide the agency in determining its manifold actions?

Functions of Atomic Development Authority

In the Field of Raw Material

The first purpose of the agency will be to bring under its complete control world supplies of uranium and thorium Wherever these materials are found in useful quantities the international agency must own them or control them under effective leasing arrangements. One of its principal tasks will be to conduct continuous surveys so that new deposits will be found and so that the agency will have the most complete knowledge of the world geology of these materials. It will be a further function of the agency constantly to explore new methods for recovering these materials from media in which they are found in small quantities.

In this way there will be no lawful rivalry among nations for these vital raw materials. Through its surveys the agency will be better informed about their geology and extraction than any single nation could possibly be. It will be in a better position to discover whether and where illicit operations might occur than any inspection force could possibly be. This is not to say that there is no risk of illicit operations; any plan, any system of safeguards, involves some risk. The question that must be answered in appraising the dangers is whether the risk is so large that it is better to make no attempt at international control and abandon the world to national atomic armament.

As we have pointed out earlier, if the Atomic Development Authority is the only agency which may lawfully operate in the raw materials field, then any visible operation by others will constitute a danger signal. This situation contrasts vividly with the conditions that would exist if nations agreed to conduct mining operations solely for proper purposes; for surreptitious abuse of such an agreement would be very difficult to detect. It is far easier to discover an operation that should not be going on at all than to determine whether a lawful operation is being conducted in an unlawful manner.

For the purpose of its surveys, the international agency would require access to various nations for its geologists and mining engineers. But the known geology of the critical materials is such that it may be possible to limit the degree of access from the start. And, as explorations proceed and various areas are eliminated it may be hoped that the *need* for access would narrow, rather than expand, but at all times the right of access to any region for re-survey in the light of new knowledge would be necessary.

All the actual mining operations for uranium and thorium would be conducted by the Authority. It would own and operate the refineries for the reduction of the ores to the metal or salt. It would own the stockpiles of these materials and it would sell the by-products, such as vanadium and radium. It would also provide the necessary supplies of uranium and thorium for the present limited commercial uses. All these sales would presumably go through normal commercial channels.

In the field of raw materials as in other activities of the Authority, extremely difficult policy questions, with the most serious social, economic, and political implications, will arise. How shall nations and individuals be compensated for reserves taken over by the Authority? As between several possible mines in different areas, which shall be operated when it is clear that the output of all is not presently required? How can a strategic balance be maintained between nations so that stockpiles of fissionable materials will not become unduly large in one nation and small in another? We do not suggest that these questions are simple but we believe that practical answers can be found. An attempt to suggest an approach to such answers is made later where the general question of policies of the Authority is discussed.

Production Plants

The second major function of the Authority would be the construction and operation of useful types of atomic reactors and separation plants. This means that operations, like those at Hanford and Oak Ridge and their extensions and improvements, would be owned and conducted by the Authority. Reactors for producing denatured plutonium will be large installations and by the nature of the process they will yield large amounts of energy as a by-product. As the technology of power development by this method expands, ways will be found for utilizing this power both as heat and as electricity. The existing plants are not designed to operate at a sufficiently high temperature for the energy to be used for the generation of electrical power. One of the first research and development problems of the Authority would be to develop designs of reactors such that the energy released would be in a form useable for the generation of electric power.

These production plants are intrinsically dangerous operations. Indeed they may be regarded as the most dangerous, for it is through such operations that materials can be produced which are suitable for atomic explosives.

In addition to questions similar to these mentioned in the case of raw materials, many new ones suggest themselves in relation to such production plants. What measures can be taken to assure the minimum degree of danger in design of plants and output? What measure can be taken to assure the minimum danger of diversion? What measures can be taken to assure location of plants that both will permit the disposition of by-product power and heat in areas where they are most needed and at the same time will maintain a strategic balance between nations so that none may be inspired with fear lest the existence of plants in another would give that nation an advantage if it suddenly developed aggressive intentions? How will the vast amounts of by-product power be disposed of by an international agency operating geographically within a national economy? Like the questions previously stated, these are not easy to answer. But here again we think that answers can be found and we venture later to suggest a way of going about the process of formulating answers.

Research Activities

We have already referred to the research that the Authority will conduct to extend the field of knowledge in relation to recoverable raw materials. We have referred to research in power development. There will be many other forms of research in which the Authority will have to engage, relating to simplifying reactors and the like.

Here we desire to emphasize that the field of research in its broadest sense is the field in which the greatest opportunities present themselves for national and private activities. For research in relation to the application of discoveries relating to atomic energy is a great area of work which, in the context of the general plan of safeguards herein proposed, is non-dangerous. For the reasons already indicated the Authority itself will have to engage in a wide variety of research activities. For example, one of the important things that the Authority will have to do is research in atomic explosives. We are by no means sure that important new discoveries in this field do not lie ahead. Possibly the study of atomic explosives may yield by-products useful in peaceful activities. But this will not be the main purpose of the Authority's research. Only by preserving its position as the best informed agency will the Authority be able to tell where the line between the intrinsically dangerous and the non-dangerous should be drawn. If it turns out at some time in the future, as a result of new discoveries, that other materials lend themselves to dangerous atomic developments, it is important that the Authority should be the first to know. At that time measures would have to be taken to extend the boundaries of safeguards.

But, as we have said, it seems highly desirable that while conducting its own necessary research the Authority must not discourage but rather must give vigorous encouragement to research in national or private hands. The universities and public technical agencies, industrial enterprises, research institutes, all will have a direct interest in participating in these activities. A good example of the opportunities in this direction is afforded by considering the situation with respect to radioactive isotopes. It will be possible for the Authority to produce these isotopes in primary production plants. The chemical separation and purification of them, however, is an involved industrial process, but involves no threat to security; states or private organizations should be encouraged to go into these activities. But for many purposes it will also be possible to produce these isotopes in small non-dangerous reactors that can be safely operated by nations or private institutions. In the interest of avoiding overexpansion of the international Authority, we think a deliberate effort should be made to encourage the production of isotopes in national hands.

It would be premature, of course, to seek now to draw any hard and fast line between the functions that the Authority should have in producing these isotopes and the functions which ought to be left to nations and their citizens. But it is important to be aware at all times of the necessity for taking advantage of the opportunity

for promoting decentralized and diversified national developments and of avoiding unnecessary concentration of functions in the Authority. The field of research is an area in which the keenest awareness of this problem will be essential when the time comes to draft a charter and when thereafter the time comes for establishing the detailed administrative policies of the Authority.

Up to now we have been dealing with the exclusive proprietary functions of the Atomic Development Authority. Except as to the discussion just concluded we have been describing the things it must do wholly withdrawn from national hands. We turn now to a discussion of functions more regulatory than proprietary in character. These are the functions through which the agency will maintain moderate controls over the activities that will be conducted by nations or private agencies. For convenience we shall refer to these activities as "licensing" functions though we think that various devices besides licensing may in fact be developed to do the job.

Licensing Activities

The uranium and thorium which the Authority mines and the fissionable materials which it produces will remain the property of the Authority. By such ownership the Authority could determine the conditions under which these dangerous materials might be used. Through the lease of such denatured materials to those desiring to build and operate reactors of various non-dangerous kinds, the personnel of the Authority could have access to the establishment in which such material is used. Moreover, through its own research and development activities and through establishing cooperative relationships with research and development laboratories in this field throughout the world, the Authority would be in a position to determine intelligently safe and unsafe designs of reactors for which it might lease its fissionable materials.

In the following paragraphs we shall refer to three of the general types of activities of great importance in the field of atomic energy which, as already indicated, are or can be made sufficiently safe to be carried on by nations under suitable arrangements with the proposed Authority. These types of activity, as we have pointed out earlier, open up a broad field for national and private exploitation of the useful applications of atomic energy. In particular, they will permit broad scope for research and development in this field by nations and private groups within such nations.

One of the first licensing activities of the Authority might be in the field of research reactors for which it would furnish on lease denatured plutonium or U 235. In carrying on such operations, presumably those desiring to build such research reactors would submit their designs to the Authority both for approval and for advice as to improvements, and would obtain a license to build such a reactor and lease of the denatured fissionable material needed for it. There would be a minmum of danger involved in allowing the construction and operation of research reactors not exceeding a prescribed power level. As we have seen, the amounts of fissionable ma-

terial which might be produced through their use would be so small that for any individual unit, or even for units in one country which might number a dozen or more, there would be no real danger in terms of producing material sufficient for use in atomic explosives. Presumably the Authority from time to time would send its research personnel, in the dual role of research workers and inspectors, to the laboratories in which these reactors were used, but a minimal inspection would be needed. Moreover, such research reactors would fulfill to a large extent the urgent requirements for further intensive scientific research in this field. Presumably licenses and leases of material would be arranged between the Authority and individual nations so that the Authority would not be dealing directly with private groups within nations.

The Authority would also license and lease in the same manner as described for research reactors the construction and operation of reactors for making radioactive materials. There may well be, as sugested above, a field for the national or private production of such radioactive materials which will require a pile to produce materials for industrial and other peaceful uses. The fissionable materials leased by the Authority would always be in the form of denatured plutonium or U 235.

Within the next few years, the Authority should also be in a position to license the construction and operation of power piles and to furnish on lease denatured plutonium or U 235. The design of such piles would have to be carefully reviewed, and the construction perhaps should be inspected by the Authority, to insure that the pile was not readily convertible to a dangerous form. For example, there should be no provision within such piles for the introduction of uranium or thorium. Iron or lead might be required as structural materials and if these were made non-removable, there would be a large factor of safety against abuse. Such power reactors would "burn" the active materials and require replenishing from time to time. The fissionable materials for such power reactors would be derived from the operation of the production plants of the Authority. There is no prospect that for several years such power reactors as described here could be licensed, for the reason that there would not be enough fissionable materials produced in the plants of the Authority. Thus there is a reasonable period during which research and development may proceed both in the laboratories of the Authority and in national and private groups throughout the world, as a result of which much more will be known as to the safe and unsafe features of design prior to the time when decisions will be required.

The questions of policy that arise in relation to the licensing activities of the Authority will likewise require the utmost in ingenuity and resourcefulness for their solution. How shall control be exercised lightly enough to assure the free play of national and private enterprise without risk to security? How shall facilities and materials available for national and private exploitation be allocated and at what

cost? How may safe activities, assigned to national hands, be withdrawn if new discoveries show them to be dangerous? Again, we do not minimize the difficulties. We say only that we believe them to be of manageable proportions, and that techniques can be devised to facilitate solutions.

Inspection Activities

Throughout this report we have recorded our conviction that international agreements to foreswear the military use of atomic weapons cannot be enforced solely by a system of inspection—that they cannot be enforced in a system which leaves the development of essentially dangerous activities in the field of atomic energy in national hands and subject to national rivalry, and, to insure against diversion of these activities to aggressive ends, relies upon supervision by an agency which has no other function. But inspection in a wide variety of forms has its proper place in the operations of the Atomic Development Authority—it has a proper and essential place. Sometimes it may take a form scarcely recognizable as inspection, but that may be regarded as one of the virtues of the proposal.

It may at the outset be useful to recall some of the factors which lead us to believe that as a function of the Atomic Development Authority inspection can be effective. We do not by this wish to suggest that the necessary inspection functions are trivial or that they can be carried out without inventiveness and effort. We do believe that the proposals of this report create a framework within which such inventiveness and such effort can be effective.

In the inspection of declared and legal activities—to be sure that they are really legal—it is of the greatest advantage that the operations can themselves be so conducted as to make this inspection and control easy. The Atomic Development Authority will have the double responsibility of technically effective development, and of safety. It would be in a position to insure that in the plan of operations, in the physical layout, in the system of audits, and in the choice of developments, full weight and full consideration can be given to the ease of detecting and avoiding diversion and evasion. Thus, the Authority may conceivably find it unwise to exploit certain types of deposits because of the difficulties they present to adequate auditing. The Authority may have reason to decide on one or another method of the separation of isotopes because it lends itself more readily to control. In the location of its operations, it will be in a position to take into account political and sociological factors which might make control difficult, or to allow such considerations to influence its choice of operating personnel and procedures. We attach great weight to the importance of unifying at the planning stage the requirements of development and control. We also attach great weight to the far-reaching inseparability of the two functions in the personnel of the development authority.

As we have pointed out repeatedly, the Authority will be aided in the detection of illegal operations by the fact that it is not the motive but the operation which is illegal. Any na-

tional or private effort to mine uranium will be illegal; any such stockpiling of thorium will be illegal; the building of any primary reactor or separation plant will be illegal. This circumstance is of very great importance for the following reason: It is true that a thorough going inspection of all phases of the industry of a nation will in general be an unbearable burden; it is true that a calculated attempt at evasion may, by camouflage or by geoghaphical location, make the specific detection of an illegal operation very much more difficult. But the total effort needed to carry through from the mine to the bomb, a surreptitious program of atomic armament on a scale sufficient to make it a threat or to make it a temptation to evasion, is so vast, and the number of separate difficult undertakings so great, and the special character of many of these undertakings so hard to conceal, that the fact of this effort should be impossible to hide. The fact that it is the existence of the effort rather than a specific purpose or motive or plan which constitutes an evasion and an unmistakable danger signal is to our minds one of the great advantages of the proposals we have outlined.

We have frequently emphasized the related difficulties of providing in an inspection agency personnel with the qualifications necessary for that work, and with enlightened and constantly improving understanding of the technical realities. We believe that these problems can be solved in an Atomic Development Authority to which is entrusted the technical exploration of the field, and in which inspection activities will be carried out in part by the very personnel responsible for the new developments and in part by the men of the same organization, who have access to, and who have an interest in, the research and development activities of the Authority. We do not wish to overemphasize the advantages that may arise from the free association of the Authority's scientists and experts with those engaged in private or national undertakings, but we believe that if a serious effort is made to cultivate this association it will greatly reduce the chance of evasive national or private action, or of the existence, unknown to the Authority, of technical developments which might constitute a potential danger. As an example of an association which would on technical grounds be most appropriate for the Authority, we may cite the problem of power. The Authority will be engaged in the production of power. It will be engaged in licensing power plants of non-dangerous type for private or national operation. It should take advantage of these associations to be informed about the power requirements which play so large a part in the operation of separation plants.

It will be seen that we do not contemplate any systematic or large-scale inspection activities for the Authority except those directed to the control of raw materials. It is our hope—and we believe it a valid hope—that when the Authority is in full operation it will, through the application of ingenuity to the problem, have obtained a sufficiently complete control over raw materials and the fissionable products so that no elaborate and formal inspection procedures will be needed to sup-

plement it. It is clear that final decision on this matter must take into account the events of the transition period from our present condition to that of the full operation of the Authority. It is also clear that the more rapidly the initial steps leading to the Authority's control of raw materials are taken, the greater the chance of the elimination of the more burdensome forms of inspection.

The geological survey, while in a sense inspection, will be focussed on a world-wide search and survey for the discovery of the essential raw materials. In the conduct of research and development, and through the location of the Authority's laboratories in various parts of the world, the Authority should become cognizant of a wide range of research and development activities in various countries. Therefore, the purpose of inspection would be served in that personnel of the Authority should be currently and intelligently informed regarding national and private research and development activities in this field.

In operating mines, refineries, and primary production plants in various countries, the personnel of the Authority will likewise acquire insight regarding the activities and trends in various countries. In its licensing activities the Authority will maintain contact with the research and development laboratories authorized to use reactors. Exchange of personnel, visits, and even formal inspection, may all be involved.

In licensing power reactors which are somewhat less safe than research reactors, the Authority would send its representatives to inspect or visit these plants at frequent intervals. Such personnel would presumably be trained in the development or engineering branches of the Authority and their primary purpose might well be to furnish engineering services and advice to the operators. The inspection that would actually result would be far more effective than any direct attempt to inspect.

Under the relations described between the Authority and national or private groups using denatured fissionable material, the inspectors would have a right of access deriving from the terms of the license and lease. Furthermore, if the Authority conducted the operations described, it would have within its organization a unique knowledge of the whole field of atomic energy and the changes in that field, which are almost certain to be rapid if it is developed in a healthy manner. To the extent inspection was required it could be done by competent engineers or scientists who would be far more knowledgeable than those inspected and who could furnish useful aid and advice at the same time.

In the course of its activities, the Authority might acquire information which would cause it to suspect evasions or violations in places to which it did not have the right of access for geological survey or for inspection of installations using leased material. Some means would have to be provided so that the Authority by making out a prima facie case would be granted access to the suspected plant or laboratory. This might be arranged through the presentation of such a request to some international body

such as the International Court. If the Court were satisfied with the adequacy of the reasons presented by the Authority, it might then request the nation in which the suspected activities were located to grant access to representatives of the Authority. This seems to us one of the possible means of approach to the limited problem of detection of evasions that would be present even under the Atomic Development proposal. The procedure seems sufficiently limited in its effect upon national sovereignty to be practical. We recognize that the idea raises a host of questions that would have to be answered before the feasibility and effectiveness of the device could be established but we think it worthy of this further exploration.

Organization and Policies of Atomic Development Authority

➤ IN THE LIGHT of the scientific and technological facts and of broad human and political factors, we have undertaken, up to this point, to describe the kind of functions that an Atomic Development Authority would have to be given in order to be effective. In considering the problems of organizational structure and detailed policies for such an authority it is also clear that the facts concerning atomic energy are decidedly pertinent. But as to these problems, there is much relevant experience in the general field of international organization. Obviously the systematic approach necessary for a solution of these problems must draw heavily on that experience.

But there is an important question of timing. It would be premature now to seek definitive answers to many of the questions as to organization and policy. For in order to have validity the answers will have to be the product of international discussion and deliberation rather than any unilateral statement of a detailed plan.

In considering the type of organizational problem involved in setting up an Atomic Development Authority under the United Nations, it should be readily possible to find helpful analogies in other international operations, public and private, and even in national activities. In the course of our discussions numerous questions concerning these matters have naturally occurred to us as they would to anyone studying the international issues created by atomic energy. It has been necessary to reflect intensively on the possible answers to such questions as a means of testing the soundness of our main conclusions. We present here some of the results of our own discussion and reflection, not in the form of a systematic statement but rather for the purpose of illustrating the types of questions that arise and possible answers which occurred to this group.

One of the key problems of course will be the question of personnel. It will be of the essence to recruit that personnel on a truly international basis, giving much weight to geographical and national distribution. It does

not seem to us an unreasonable hope that the organization would attract personnel of high quality. For the field of knowledge is one in which the prospects for future development have become an absorbing interest of the entire world. Certainly there is a far better chance that the Authority would attract personnel of a high calibre than that any purely policing organization would do so. At any rate, it is clear that the success of the organization would depend upon the quality of the administrators, geologists, mining experts, engineers, physicists, chemists, and other personnel, and every possible effort must be made to establish the kind of organization that will attract them.

It is not alone necessary for the organization to be thoroughly informed in the field of atomic energy. It will also be necessary for the nations of the world to be thoroughly informed at all times about the operations of the Authority. There are many ways of assuring this necessary degree of accountability on the part of the Authority to the nations and peoples whose instrument it will be. Some integral organ of the United Nations, perhaps the Security Council itself, will need to serve as the overseeing body for the Authority. But it could do so in ways generally comparable to those employed by Congressional appropriations and investigating committees and the Bureau of the Budget in relation to governmental institutions in the United States. Detailed measures would have to be worked out to assume the proper connection between such an overseeing or "accountability" body and the Atomic Development Authority itself. Ways will also have to be worked out to assure that individual nations may maintain enough direct contact with the organization to give them a sense of intimate relations with it. This need will be served in part by the fact that the staff of the organization will be recruited from various nationalities. The operations of the Authority in its licensing activities, where it will be dealing directly with the individual states, will also be one of the ways in which this objective is accomplished. For in this field there will be constant collaboration between the Authority and individual states in working out the detailed scientific technological, and political problems which will cluster around the Authority's licensing activities. None of these matters appears to present insuperable difficulties.

The foregoing is intended merely as a statement of the possibilities for actually creating an organization that will have sound relations with the United Nations and with individual states. These possibilities must be made the subject of further exploration as intensive as that which we have directed to the scientific and technological facts concerning atomic energy itself.

➤ NATIONAL SECURITY *during transition to international control is provided for in the fourth and concluding section of the State Department Report. Written by atomic scientists of the committee under the chairmanship of David Lilienthal, this Report was presented to the United Nations by Bernard Baruch, and is currently being referred to by his name. Read Part IV in the July* CHEMISTRY

Petroleum Source of Processing Materials

▶ PETROLEUM, best known as a source of fuels, lubricants, and raw material for synthetic organic chemicals, is now in wide use as a source of processing materials essential in many industries. Over 30 basic industries are now using these materials, states John C. Dean of the Socony-Vacuum Oil Co., and the individual applications are numbered in the thousands.

A summary of some of the more important petroleum products used in industry as processing materials is given by Mr. Dean in *Chemical and Engineering News*, published bv the American Chemical Society.

"The scope of petroleum's utility as a processing material," he states, "is virtually unlimited."

Paraffin wax, petrolatum, microcrystalline waxes, wax emulsions, naphthenic acids, petroleum resins and sulfonates, and uncompounded oils are among the processing materials mentioned by Mr. Dean. The public is acquainted with paraffin wax, he says, but does not appreciate that some 80% of the 700,000,000 pounds produced each year is used on paper and paper products such as bread wrapping and drinking straws. It had important war uses as well.

Petrolatum, a refined form of which is sold to the public as vaseline, is used in paper, cosmetics, carbon paper, and as a waterproofing material for canvas and rock wool. Microcrystalline waxes were first made in 1926, Mr. Dean states, when it was discovered that oil could be removed from petrolatum to produce a hard, tough, flexible material. These waxes served an extremely important war job in protecting from corrosion military supplies and equipment shipped overseas.

Wax emulsions are suspensions of wax in water stabilized with suitable emulsifiers and dispersing agents. One of the chief advantages of a wax emulsion is that it permits small quantities of the wax to be applied in controlled amounts. One of the most important uses of the material is the treatment of textiles to impart a water-repellent finish.

Naphthenic acids, like fatty acids, can be converted into soaps, in which form they have their greatest uses.